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THREE YEAR TOPICAL INDEX

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The topical reference does not necessarily bear the author's title of the article, but aims rather to give a good conception of the subject matter. The author's name and a short description follow; further characteristics are abbreviated by the letters T, C, D, etc.

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THE
ELECTRIC JOURNAL

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The Electric Journal

"Our purpose is definite: to publish a journal for young engineers, containing material suited to their needs and written in a form to meet their education and experience. To what extent we accomplish this purpose, the JOURNAL itself will determine.

"Our aim therefore is to be of service to the young engineers —and it is hard to find an electrical engineer who is not young— in making him a better engineer and a broader man. A Journal of Engineering and a Journal of Inspiration."

The foregoing paragraphs appear in the editorial announcements in the first issues of Volume I. and of Volume II. of this Journal.

They may stand as statements of purpose and aim in this the first issue of Volume III.

To what extent the purpose announced two years ago has been accomplished, the support which the JOURNAL has received from its readers may be taken as a fair indication.

The words of encouragement and commendation and the substantial sources from which they have come have not only been gratifying but have indicated that the JOURNAL has been meeting a real need among many classes of electrical engineers.

The standing of the JOURNAL may also be measured numerically. While this is not necessarily a true criterion of engineering excellence, it is nevertheless a convenient way to measure the appreciation with which the JOURNAL has been received.

Since the first issue of the JOURNAL there has been a continuous daily addition to the subscription list with the exception of a single day nearly two years ago. The total names on the list of paid subscribers (not including renewals) shows that over 10 000 different persons have been regular readers of the JOURNAL.

The demand for bound copies of Volume I. of the JOURNAL was so great as to justify the reprinting of a number of the early issues of which our stock had been depleted. As these first volumes have been purchased by those who were not subscribers of the JOURNAL from the beginning, but who have since become acquainted with its character, the sale of over 800 volumes is strong testimony that the JOURNAL is worth having and worth paying for.

The fact that the ideals, which some two years ago resulted in the establishment of this Journal, have in a large measure been realized, gives promise that a continuation of the same purposes and aims in the future will meet with continued endorsement and success.

PUBLICATION COMMITTEE

Electricity as a Fire Hazard

At the National Code Conference held in New York City, December 4th, just before the annual meeting of the Underwriters' National Electric Association, a number of very interesting points were brought out in a discussion of fire hazard of electrical installations as compared with other fire hazards.

For a number of years it has been the practice of the Underwriters to publish quarterly a statement of the fire losses which have been occasioned during the preceding quarter from electrical causes. The reading of one of these reports by one not familiar with fire losses, gives the general impression that electricity is a very serious fire hazard, particularly in view of the fact that figures for other losses are not given in the same publication and therefore no direct comparison can be made. These reports have been published by the underwriters for the purpose of educating their inspectors and others who have to do with the wiring of buildings and the design of various kinds of apparatus which might enter as a fire hazard. A photograph of a defective joint in wiring, together with a statement that a fire started from this defective joint, causing a loss of half a million dollars, is probably the most striking method possible of showing the necessity for following the well-known and established rules for the making of such joints. The value of such education to those who have to do with these matters is unquestioned, but, on account of the undue prominence given to the subject of electrical losses, it has been suggested that the publication of the bulletin in question either be discontinued or that it be accompanied by a general summary of the fire losses from other causes, in order that the true relative status of the electrical fire hazard may be shown in this publication.

At the meeting referred to, figures were produced which show that electricity is not a relatively serious fire hazard, and that electric wiring and electrical apparatus properly installed are the safest possible means of transmitting and utilizing energy for the production of light and power. The losses from fires due to any one of a number of causes other than electricity are annually very much greater than the electrical losses, but in the absence of comparative information, many people jump at the conclusion that it is unsafe to use electricity for any purpose on account of the danger from fire. This reason sometimes prevents the change from some of the older forms of illuminants to electricity, when, as a matter of fact, the form already in use is more dangerous than electricity properly installed.

Electrical installations improperly put in may form a serious fire hazard, as live wires can be a fire hazard even when not carrying current. An oil lamp not lighted is not a fire hazard *per se,* but the general risk in the use of oil lamps is greater than with electric lights.

The formulation and uniform enforcement of safe rules for electrical installation should therefore be a matter of prime importance to all concerned with electrical work.

A study of the relative losses from electrical causes and those from oil lamps, matches, candles, etc., as found in published tables such as the Chronicle Fire Tables (Chronicle Co., New York City) will show that the electrical hazard is comparatively very small. A further study of the bulletin published by the underwriters giving the causes of the fires due to electricity will show that the majority of the electrical fires might have been avoided by the proper installation of the wiring and apparatus.

C. E. SKINNER

Automatic Control for Electric Motors

The article by Mr. James on "Automatic Control for Large Direct-Current Motors" describes another step in the general progress of electric motor applications. While the demand for larger motors for electric traction is rapidly increasing, the demand for larger units of motor power in the industrial field is even greater. While there are a few electric locomotives having motors of three hundred or four hundred horse-power it is not uncommon to find motors of several times this power doing work in the industrial field. The handling of these large motors sometimes taxes the skill of the designer, especially when the operating conditions are very exacting. In railroad work the limiting condition is usually the endurance of the motor and not the endurance of the power supply as is often the case in industrial work. Thus it is frequently necessary to start a large motor and bring it up to speed without drawing from the line more than full-load running current, even when the motor must start with a large portion of its full load. In other cases it is desirable to start the motor in the least possible time without regard to the current consumption.

To fulfill these conditions, in the most economical manner and without danger to the operators or to the apparatus, is a problem of no mean proportions when dealing with several thousand horsepower.

It is desirable to supersede the manually operated drum controller by an automatic controller not because it is a drum controller but because it is manually operated. It is the automatic feature that is important, not how the motor circuits are made. That is, it is not a question of the kind of switch or switches used in closing the motor circuits, but the manner in which these switches are manipulated.

In determining the kind of automatic controller that will give the best results in a given case the governing conditions must all be given due consideration. If it is desirable that a given motor should be started from rest and accelerated to full speed in a certain time, regardless of any other consideration, it is obvious that a controller which is regulated by some sort of a time mechanism is what is required. Even in this extreme case an automatic controller will give better results than a manually operated one, for no one can repeat the same operation in exactly the same time.

If it is desirable that the motor accelerate to full speed with a constant current consumption irrespective of the load, a device that is controlled by the value of the current is what is required and not one that operates on a time basis. The performance of a controller of this kind is even more difficult to duplicate manually than the one with a constant time element.

In some cases it is desirable to have a combination of both time and power consumption to regulate the control apparatus.

Automatic control does not necessarily mean remote control nor does remote control necessarily imply automatic control.

These two functions of the control apparatus are quite independent and distinct. Remote control may be automatic or non automatic and likewise a control that is not remote may be automatic or non-automatic. An automatic control is one in which the cycle of operations once set in motion by the operator procedes automatically and without attention. The operator simply indicates what the control apparatus shall do and the apparatus does it at a predetermined rate and according to a predetermined plan over which the operator has no influence. If the motor is running in one direction and he wishes to reverse the direction he simply indicates this by the movement of the master controller or switch and the control apparatus must automatically bring the motor to rest and start it in the reverse direction. All this must and can be done without any danger to the apparatus or any machinery that the motor may be driving. In fact it is impossible for the operator to damage the apparatus by careless or malicious handling.

The advantages of automatic control are not confined to the use of direct-current motors but are equally applicable to alternating-current motors. Nor does the term automatic control apply only to the starting of motors. It may include the stopping and reversing or their operation at any predetermined speed. In any case the automatic control will produce results superior to any manually operated control. William Cooper

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Electric Railway Engineering

The growth of electric traction has lead to the development of a specific group of engineering problems. These problems, broadly speaking, involve the application of electrical apparatus to all conditions of railway operation ranging from the ordinary street car to the heaviest express train. The questions involve both theoretical and practical elements. Sometimes they are treated as problems in higher mathematics. Some engineers on the other hand go to the opposite extreme and attempt to use their past experience without clearly recognizing many of the fundamental mechanical and electrical principles which are involved.

There is an intermediate method which involves both principles and practice.

The first article in a series devoted to electrical railway engineering appears in the present issue of the Journal. These articles will present the salient engineering features of electric railway work in a style which is general and descriptive rather than technical and mathematical. The subject will be treated by men who are in constant contact with the questions with which they deal.

It is quite appropriate that the initial article of the series appears in the same issue with Mr. Lyford's admirable presentation of the conditions which presented themselves in the notable electrification of an extensive steam railway system.

Chas. F. Scott

Thinking

The chief engineer of one of the largest and best managed street railway systems in the country said the other day, "I will not have men who have not had a college training at the head of any department. I endeavor also to have as their assistants men with a technical training. While these men cannot be held in the organization long because there is little room for advancement, yet their higher average intelligence makes it worth while to have them."

This frank statement of the value of a technical training is refreshing. The young men who come to this road have no experience in the work they undertake and have little concrete knowledge to apply to the particular tasks they are set to. They are valuable not because of what they know, but because they have learned to reason from cause to effect and conscientiously to apply a rule for experimentation laid down by Sir Francis Bacon some two hundred years ago—to vary one condition in order to discover its effect in the final result. They have been taught to think.

J. H. Smith

ELECTRIC RAILWAY ENGINEERING*

GENERAL PRINCIPLES RELATING TO THE OPERATION OF CARS OR TRAINS

F. E. WYNNE

THE main object of any railway is to transport passengers or freight from point to point along the lines and to traverse the distance in a given time. Assuming that the location and construction of the roadbed and the track have already been considered, it is then the province of the railway engineer to determine how the traffic shall be handled and what equipment is needed, that is, what type and how many cars shall be purchased, how fast and how often they shall be run and what apparatus is necessary to operate them. The railway engineer has not only the car equipments to deal with but also the power stations, sub-stations and distributing lines. For the best results these points should be given careful consideration before the road is completely located and the track constructed, so that the location and construction may be adapted to the proposed service.

A number of the general principles relating to the operation of cars or trains are independent of the motive power which is used and these will be considered first.

In operation over a railroad where there are a number of stops to be made, the speed of a car varies widely from time to time and, in general, follows a definite cycle of operations which is repeated again and again. Starting from rest the speed of the car is increased or accelerated, rapidly at first, then more and more slowly until a practically uniform speed is reached. This uniform speed is maintained for a certain length of time. The power is then cut off and the car allowed to drift or coast, in which case, of course, the speed decreases slowly. Finally the brakes are applied and the car brought rapidly to a standstill in order to take on or discharge passengers or freight, after which the same operation is repeated.

By plotting a curve in which the instantaneous speeds of a car are ordinates and time the abscissae, the different periods above mentioned can readily be seen. Such a curve is called a speed-time curve, and is extremely useful in studying railway conditions. Typical curves of this sort are shown in Figs. 1 and 2 for a car making runs of one-half mile and one mile respectively, with stops of eight seconds each. The various periods on these curves are: acceleration, *AB;* uniform speed, *BC;* drifting or coasting, *CD;* braking, *DE;* and standstill, *EF.*

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*This article is the first of a series upon Electric Railway Engineering. These articles are based upon a course of lectures delivered by Mr. Clarence Renshaw before The Electric Club. The original notes have been elaborated and the treatment of the subject has been made more comprehensive. The preparation of the series has been under the direction of Mr. F. E. Wynne, of the railway division of the engineering department of the Westinghouse Electric & Mfg. Company.

Referring to either figure, the distance in miles divided by the total time, *AF*, in hours gives the schedule speed in miles per hour for the run. In the case of a line making a number of such runs between terminals, the schedule speed would be calculated from the time *A* of the first run to *E* of the last run. The schedule speed

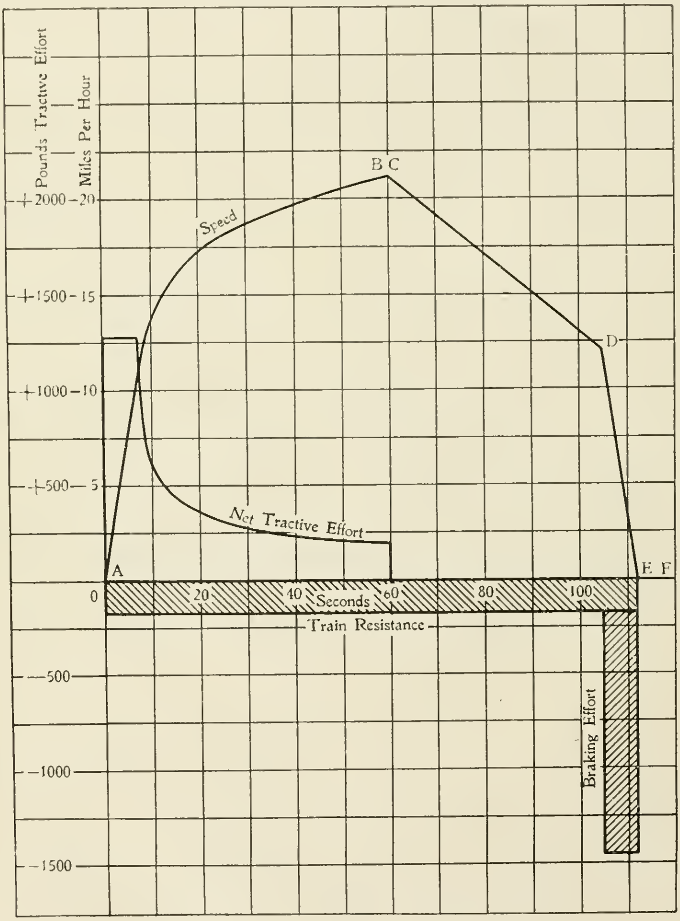

FIG. 1—17 TON CAR, ONE-HALF MILE RUN

is sometimes called the commercial speed for it is evident that this is the speed which is of most importance to the patrons of the road.

The distance in miles divided by the time, *AE,* during which the car is actually in motion, gives the average running speed. It is evident that in the service where stops are frequent, there may be considerable difference between the average running speed and the schedule speed so that they should be carefully distinguished. On the other hand, where the stops are few and short there may be but little difference.

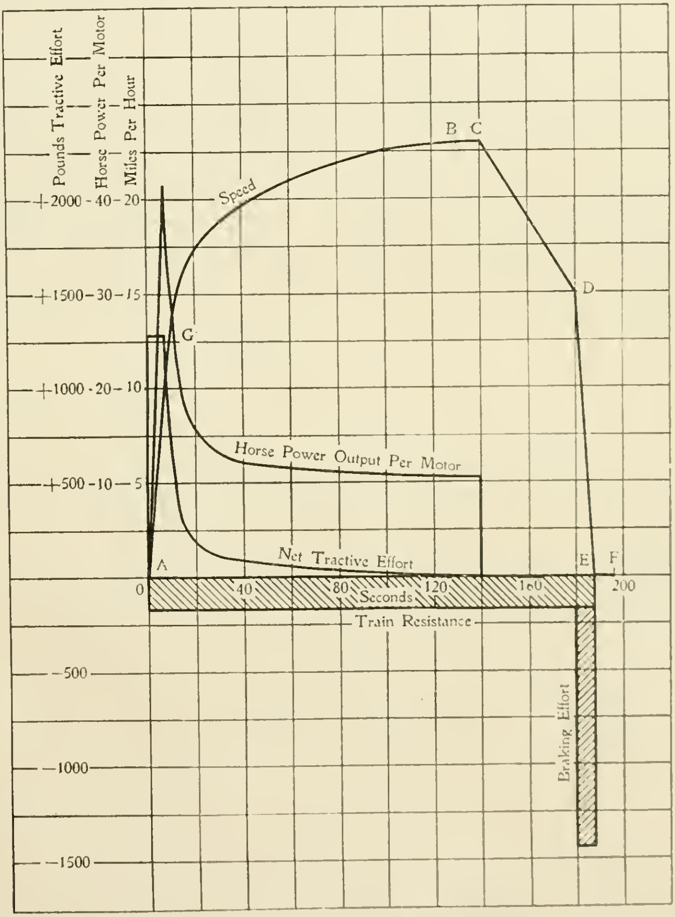

FIG. 2—17 TON CAR, ONE MILE RUN

The speed at the point *C* is called the maximum speed and since in almost any class of service this will differ widely from the schedule speed, it also should be carefully distinguished therefrom.

The slope of the lines *AG* and *DE* are measures of the acceleration and braking rates respectively. If, for instance, a speed of 13 miles per hour is reached at *G*, Fig. 2, in ten seconds from the start, the rate of acceleration is 1.3 miles per hour per second, and, in the same way, if the car is stopped from a speed of 15 miles per hour at *D* in 7.5 seconds, the rate of braking or retardation is two miles per hour per second.

The more rapid the rate of acceleration and braking in any given run, provided the same maximum speed is reached, the greater will be the schedule speed. On the other hand, the more rapid the rate of acceleration and braking, the lower is the maximum speed required for a given schedule. The shorter the length of run, the greater is the ratio of maximum speed to schedule speed and the slower is the possible schedule speed. The longer the stop after a given run, the greater is the ratio of average running speed to schedule speed. A more detailed discussion of these relations will be given when the calculation of speed-time and power curves is considered.

RELATION BETWEEN TORQUE AND POWER

The power developed by an electric motor depends on both the torque and the speed and is proportional to their product. By torque is meant the pounds pull at one foot radius from the center of the armature shaft. Power is the rate of using torque. The relation may be illustrated by imagining a cable wound on a drum two feet in diameter and used to hoist a load without the use of intermediate pulleys. The tension in the cables corresponds to the torque. If the tension is 330 pounds and the speed is 100 ft. per minute, work is being done at the rate of 100x330=33 000 ft. lbs. per minute, or one hp. With the same tension (330 pounds) in the cable and a speed of 200 feet per minute, the power is 200x330=66 000 ft. lbs. per minute, or two hp. If the load is stationary, the torque may be the same but no power is developed. From the foregoing example it is evident that with a given torque, power is proportional to the speed. Similarly, at a given speed, power is proportional to torque.

RELATION BETWEEN TORQUE AND TRACTIVE EFFORT

The force used to propel a car is ultimately exerted at the tread of the car wheels and is called tractive effort. Since the torque of the motors produces tractive effort, there must be a definite relation between them. What this relation is may be determined by following the transition from torque delivered by the motor shaft to tractive effort. In being transmitted from the motor to the car wheels, a small amount of power is lost in the gears connecting the motor shaft and the car axle. The speed of the car axle is changed from that of the motor shaft by the ratio of pinion diameter to gear diameter. Hence, as the power is approximately the same at the motor shaft and at the car axle, the torque at the axle must be the motor torque multiplied by the ratio of the gear to the pinion. This ratio is most conveniently expressed by using the number of teeth on the gear and pinion as measures of their diameters. Since the torque at the axle is measured at one foot radius and the tractive effort is measured at the wheel tread, the tractive effort is to the torque at the axle as one foot radius is to the wheel radius in feet. Wheel size being usually given as inches diameter, the above ratio may be written as 24 inches is to the diameter of the wheel in inches.

TRAIN RESISTANCE

The tractive effort required to propel a car at uniform speed on straight level track is only that necessary to balance the train resistance at that speed. Train resistance is a variable quantity and is difficult to determine. Among the things affecting its value are the weight, size and shape of car; speed, condition of track, wheels, and motor and axle bearings. Train resistance has three component parts, namely, journal friction, rolling friction and wind resistance. Journal friction is practically independent of speed. Rolling friction is inversely proportional to speed. Wind resistance is proportional to some power of the speed as yet undetermined. For the consideration of the general operation of single cars at low speeds, the train resistance may be taken as having a constant value of 20 pounds per ton.

TRACTIVE EFFORT AND POWER REQUIRED FROM STANDSTILL TO MAXIMUM SPEED

Acceleration is the rate of change of velocity. When the change is from a lower to a higher speed, the acceleration is said to be positive. Acceleration which decreases speed is negative. Whenever there is a change of speed, there must be a force which causes the change. A car running at any speed possesses kinetic energy of the value, $\frac{1}{2}MV^2$, where M is the mass in pounds, and V

is the speed in feet per second. Therefore, to bring a car from any speed to a higher speed requires energy which must be imparted to the car through the action of some force. Consequently more tractive effort than that which is sufficient to balance the train resistance must be exerted in bringing a car from rest up to any speed or from one speed to a higher speed. In the present consideration, the friction of rest is neglected because it is only momentary and of very uncertain value.

A force of 91.3 pounds for accelerating one ton at the rate of one mile per hour per second is required to produce rectilinear acceleration alone. Additional force is required to accelerate the revolving parts of the car and equipment, that is, the motor armature, gears, axles and wheels. This force is difficult of determination and varies with the sizes and weights of the revolving parts and with the distribution of weight in those parts. Calculations in several specific cases have shown that a force of 100 pounds per ton for accelerating at the rate of one mile per hour per second makes satisfactory allowance for the rotary acceleration. The force required for acceleration is called net tractive effort. For example, to accelerate a 17-ton car at the rate of 1.5 miles per hour per second (so that at the end of ten seconds its speed shall be 15 miles per hour more) requires a force equal to [(100x17x1.5=2 550 pounds net tractive effort)+(20x17=340 pounds train resistance)] or a total tractive effort of 2 550+340=2 890 pounds.

In starting a car, the acceleration at first is very great, and a large tractive effort is required. The acceleration gradually falls off as the speed increases until the total tractive effort is just sufficient to balance the train resistance. Under this condition the car runs at a uniform speed. Figs. 1 and 2 show the tractive effort and hp curves as well as the speed time curves.

EFFECT OF GRADES

Grades are usually expressed in per cent., that is, the number of feet vertical rise in 100 feet horizontal distance. When given in feet per mile, as is sometimes the case, grades are readily converted into per cent. by dividing the feet rise per mile by 52.8 (the number of 100 feet in a mile). When a car runs up grade, work must be done in actually lifting the car the amount of vertical rise. This work is in addition to the amount required to overcome the train resistance, which of course is present on grades to the same extent as on the level. Hence an additional force must be exerted to do this work. If, in Fig. 3, *OW* represents the weight of the car, this weight may be divided into two component forces, *OH* and *OK*. *OH* is perpendicular to the line of the grade *AB* and represents the pressure of the wheels on the rails. *OK* is parallel to *AB* and represents the component of the weight tending to make the car run down the grade. The force, *OH*, is balanced by the upward pressure of the rails against the wheels and offers no resistance to motion along the grade. If, however, motion is to be maintained when the car strikes an up grade, a force equal and opposite to *OK* must be added. *OK* is called grade resistance. In the figure, the force, *OK*, is to the weight, *OW*, as the vertical rise, *BC*, is to the distance, *AB*, along the grade. For grades less than 10 per cent., such as are usually found in railway work, the ratio of *BC* to *AB* is very nearly the same as the ratio of *BC* to *AC*, and may be taken as equal to it. Then, grade resistance is equal to 20

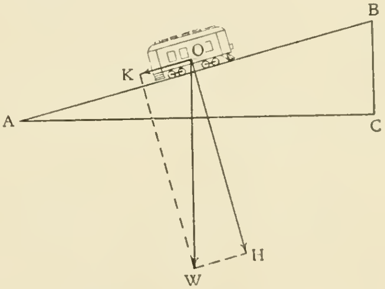

FIG. 3—CAR ON GRADE

pounds per ton weight of car for each per cent. grade. As before, the train resistance is assumed as 20 pounds per ton. Hence, to run a car at uniform speed on a grade requires [weight in tons multiplied by (20+20 times per cent. grade)] pounds tractive effort; or 40 pounds per ton for one per cent. grade, 60 pounds for 2 per cent., 80 pounds for 3 per cent., and so on.

EFFECT OF CURVATURE OF TRACK

Another element which offers resistance to the motion of cars is curvature of track. That curves do offer a resistance to motion may be seen from the fact that going around a curve is equivalent to revolving around its center of curvature. Hence with reference to this point, a centrifugal force exists due to the tendency of the car to travel in a straight line. This force is balanced by the pressure of the outer rail against the flanges of the wheels. Consequently there is friction between flanges and rails which does not exist when running on a straight track. The coefficient of friction is undetermined, but must be greater than usual because of the tendency of the flanges to bite into the rails, and also because of the slipping of one of each pair of wheels on the same axle, due to the difference in length of the outer and inner rails. Curve resistance may be taken at from 0.4 to 0.8 pound per ton per degree of curvature.

WHY SERIES MOTORS ARE USED

From the facts set forth in the previous pages, the following conclusions may be drawn. The operation of a car involves a wide variation in tractive effort and speed. The greatest tractive effort is required at the slow speed incident to starting. When running at full speed, a minimum tractive effort is needed. More tractive effort is necessary to run up grades and around curves than for running on straight level track, but it is not usually imperative that grades and curves shall be taken at full speed. In fact it is often necessary to slow down for safety in rounding a curve. From this it is seen that whenever great tractive effort is required, it may be obtained at the expense of speed. Consequently the variation in the amount of power required at different points in any cycle is less than the variation in either tractive effort or speed. It is further desirable to have the variation in load at the power house a minimum. Therefore, the most satisfactory motor for operating cars is that motor which will commutate heavy overloads, operate efficiently in coming up to speed as well as at full speed, and give a wide variation in tractive effort with the least variation of power. A brief consideration of the performance of the series type of motor and a comparison of it with the shunt type will show how the series motor is adapted to fill these conditions of railway service and the unsuitability of the shunt motor, which is typical of constant speed machines.

THE SERIES MOTOR

The performance of a direct current motor may be expressed by five curves showing for any current within its commutation limits at rated voltage: the speed, torque, input, output, and efficiency. These curves are called the characteristic curves of the motor. A typical set of such curves for a series motor is shown in Fig. 4. The input is directly proportional to the current and is determined independently of the other four characteristics. The five characteristic curves of a motor are interrelated. If, in addition to the input which is always known, there are given any two of the other four characteristics (excepting the combination of output and efficiency), the remaining two curves may be calculated and plotted. This may readily be seen from the following relations. The horse power output is equal to the product of the horse power input and efficiency. The horse power output is equal to the product of the torque at one foot radius and the speed in revolutions per minute divided by the constant 5 252.

The essential feature of the series motor is its variable field strength. Since the field and armature are in series, the load current is also the field current and the field strength varies automatically with the load, increasing with heavy loads and weakening with light loads. The varying field affects both the torque and the speed.

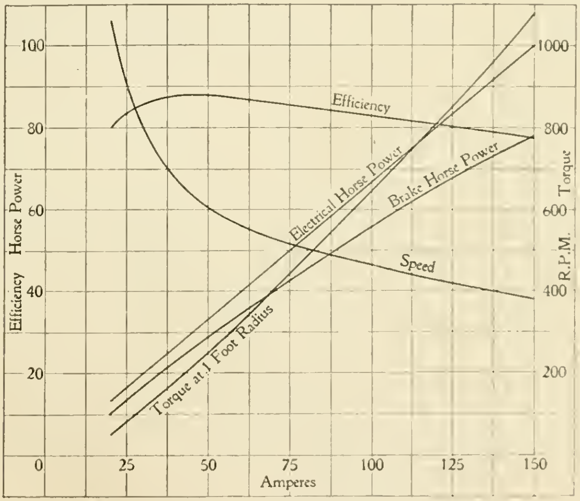

FIG. 4

Torque is dependent upon and proportional to field strength and armature ampere-turns. Each of these varies directly with the current, hence for a given increase of current, the corresponding increase of torque is much greater. In an unsaturated motor, the torque would be proportional to the square of the current. Since, however, railway motors are more or less saturated throughout the greater part of their working range, the torque variation is somewhat less than proportional to the square of the current. This may be seen from the following curves, Fig. 5, where for any given current the torque is approximately proportional to the product of the values of field strength and armature ampere-turns given for that current.

The speed of a motor depends on the number of armature conductors and the field strength. The armature must run at a speed such that the counter electromotive force generated will equal the applied voltage minus the volts drop in the motor. The drop in the motor is made up of two parts, the *CR* drop in the motor windings and the drop in the brushes and brush contacts. Fig. 6 shows a curve giving the brush drop in a certain motor at all current values from 50 to 500 amperes inclusive. Since the resistance of a motor is constant at a given temperature, the *CR* drop varies directly with the current. An increase of current gives increased drop in the motor, thus tending to reduce the speed. The field strength also increases with the current and a further reduction in

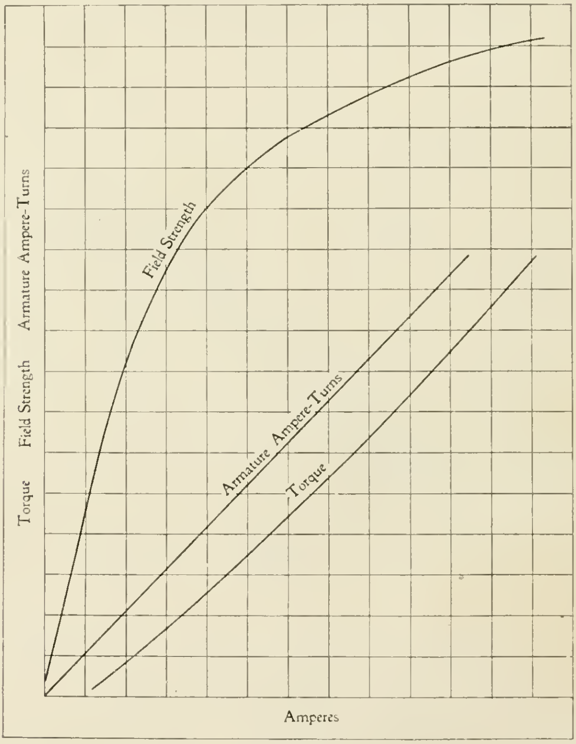

FIG. 5

speed results. Fig. 7 shows this graphically. *AB* is the applied voltage and has a constant value for all currents. *OC* shows the drop in the motor at all currents. Then the vertical distance between *AB* and *OC* at any current gives the counter electromotive force which must be generated by the motor when taking that current. The field strength is shown by curve *OF*. Since the counter electromotive force is proportional to the product of the field strength and the speed, it follows that the speed is proportional to the quotient of the counter electromotive force divided by the field strength. For an increase of current, the counter electromotive force to be generated decreases and the field strength increases, consquently the speed must decrease as shown by curve *MS*. The momentary overload to which a motor may be subjected without injury depends on the commutation. Since the series motor has a strong field whose strength increases automatically with the load, it is admirably adapted to this requirement of railway service. In general, if the current taken by a series motor is doubled, the motor will develope from two and one-fourth to three times as much torque; for example, in Fig. 4:

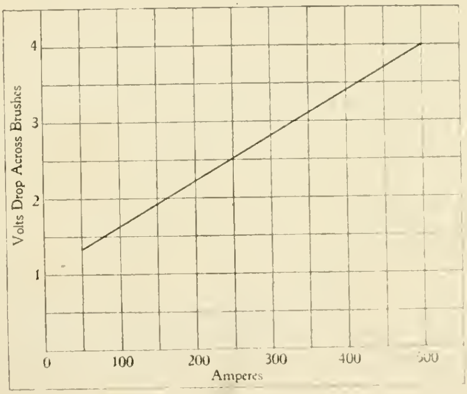

FIG. 6—BRUSH DROP

37.5 amperes (one-half load) gives 165 lbs. torque.
75 “ (full load) gives 440 “ “
150 “ (double load) gives 1080 “ “

THE SHUNT MOTOR

The essential feature of the shunt motor is its practically constant field strength. From this it follows that the torque is directly proportional to the current and that the speed is almost constant at all loads. Fig. 8 shows speed and tractive effort curves for a shunt motor giving about the same output at all currents as the series motor whose characteristics are shown in Fig. 4.

Assume that the 17-ton car previously considered is equipped with two of these shunt motors geared to give the same maximum speed (22.8 miles per hour) as in Fig. 2, then the full line curves in Fig. 8 will apply. In starting, a tractive effort of 1 430 pounds is required per motor. To give this starting effort, each series motor takes 76 amperes while each shunt motor requires 148 amperes. If we assume that the shunt motors are geared to give the same car speed at full load, the broken curves in Fig. 8 hold. At starting, each motor will take 76 amperes which is the same current as with the series motors, but the car will reach a maximum speed of only 11.8 miles per hour. With any gear ratio between the two above considered, a car equipped with shunt motors would take

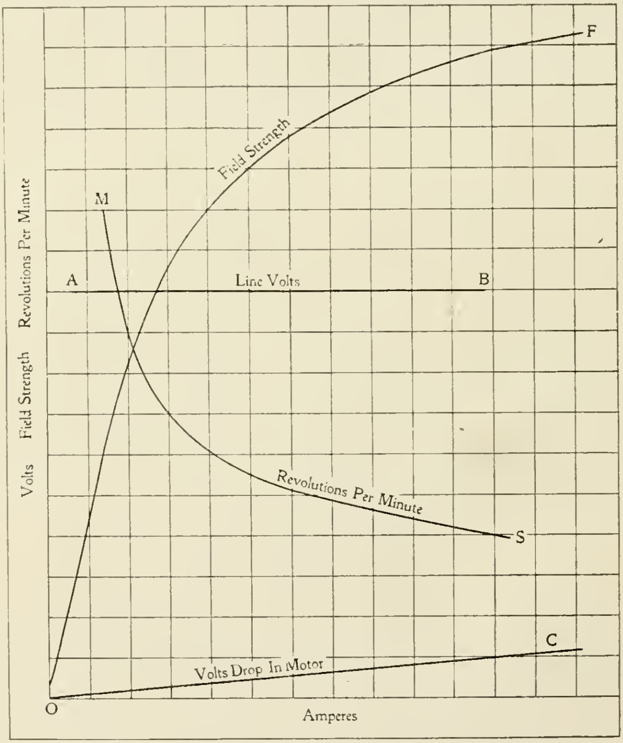

FIG. 7

greater current in starting than with series motors and the car would have a lower ultimate speed. In addition to these disadvantages, the loss of power in the rheostats when starting a car equipped with shunt motors would be greater than with series motors.

Since a shunt motor tends to run at practically constant speed, it follows that when large torque is required, it must be produced at a high speed, which results in a large output and requires a large input of power. For instance, on grades where great tractive effort is needed, the car equipped with shunt motors would run at

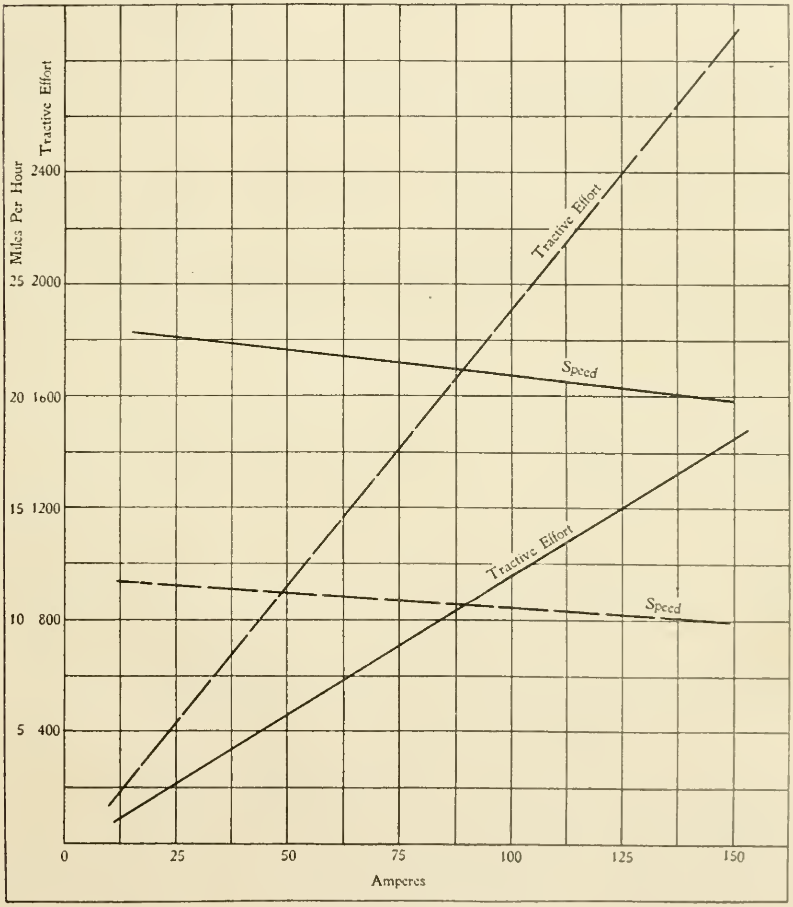

FIG. 8—SHUNT MOTOR, 500 VOLTS

almost the same speed as on the level and a large amount of power would be required. On straight level track very little power is required. Hence therefore, a great variation in the load on the power house would result.

From the above it is evident that the shunt motor is not well adapted to railway work and that the series motor meets the requirements of railway service previously outlined.

FORMULÆ

$$\text{Horsepower} = \frac{\text{Pounds torque} \times \text{Revolutions per minute}}{5252} \tag{1}$$

$$\text{Horsepower} = \frac{\text{Pounds tractive effort} \times \text{Miles per hour}}{0.375} \tag{2}$$

$$\text{Pounds tract. effort} = \frac{\text{No. gear teeth} \times 24 \times \text{Gear effic.} \times \text{Pounds torque}}{\text{No. pinion teeth} \times \text{Inches wheel diameter}} \tag{3}$$

$$\text{Miles per hour} = \frac{\text{Inches wheel diameter} \times \text{No. pinion teeth} \times \text{r. p. m.}}{336 \times \text{No. gear teeth.}} \tag{4}$$

For rectilinear acceleration—

$$\text{Pounds force} = 91.3 \times \text{Tons weight} \times \text{Miles per hour per second acceleration} \tag{5}$$

For single cars—

$$\text{Pounds accelerating force} = 100 \times \text{Tons weight} \times \text{Miles per hour per second acceleration} \tag{5}$$

$$\text{Pounds grade resistance} = 20 \times \text{Tons weight} \times \text{per cent grade.} \tag{7}$$

$$\text{Torque is approximately proportional to Armature ampere-turns} \times \text{Field strength in induction} \tag{8}$$

$$\text{Speed is approximately proportional to} \frac{\text{Applied volts—Volts drop}}{\text{Field strength in induction}} \tag{9}$$

[TO BE CONTINUED]

THE STEAM TURBINE SITUATION

EDWARD H. SNIFFIN

Sales Manager, The Westinghouse Machine Co.

THE steam turbine is no longer a matter of speculation. It has been accepted. Nearly 100 Westinghouse-Parsons steam turbine units aggregating approximately 100 000 kilowatts are in operation and the aggregate, including orders received, is over 250 000 kilowatts.

The history of the mechanical operation of power has been, for the most part, one of constructive growth in which improvements have followed in the train of experience, and development rather than invention has marked the path of progress. We came to a point, however, where the character of our prime mover had reached the culmination of its possibilities, further improvement requiring not a modification, but a radical departure in type and principle. And so the steam turbine attracted a great degree of interest and its prompt and wholesale adoption has marked the most rapid and significant change in steam engineering practice that we have ever witnessed.

Nor was the departure immature or illogical. Capital is not usually unduly venturesome. When one considers that probably no large steam-electric power plant would be conceived to-day except on the basis of steam turbines, although there has been but a few brief years' record of turbine performance, one is bound to conclude that the knowledge obtained, even though quickly acquired, has no less certainly carried conviction and established procedure. In the first place, the steam turbine was made an open book. Testing was made a special feature; elaborate data were spread broadcast through the technical press; economy tests were made a part of the manufacture. And so power users became promptly familiar with the facts, recognizing that they at once had more real information regarding the turbine than fifty years of performance had afforded on the reciprocating engine, which it was impracticable to test in the shop and almost equally so in the field. It required, then, merely to demonstrate in practical service that the turbine possessed reliability and its way was won.

The other reason for its wholesale adoption lay in its obviously great desirability as a type of power machinery. It had many things to commend it. It was cheaper in the first cost. (The current prices of turbine units are about 33 1-3 per cent. below the current prices of reciprocating engine units of four years ago.) It could be installed quickly; it took up little room; foundations were cheaper; it paralleled easily; it cost little to maintain, and its steam efficiency was uniform over wide ranges of load so that its commercial efficiency was high. Its exhaust, containing no oil, could, if desired, be used for boiler feed. Its ability to make long continuous runs was apparent, as was also the fact that violent fluctuations of load or the impost of heavy overload produced no undue stress.

Altogether, the steam turbine marked a great step forward in our type of prime mover, giving much needed relief from the limitations of reciprocating engine practice. Engineers are now finding that, apart from its merit as a prime mover, its effect on power plant design will be far-reaching in the direction of simplicity and reduction of original cost. So far, turbines have, as a rule, been installed in power plants more or less conventionally designed on the lines of piston engine practice, but we will soon have typical turbine plants, with their various other features and general arrangement co-ordinated to the simplicity and compactness of turbine design, and much of the present-day complexity, with its attending expense, will disappear. Two plants are now being designed,—one for Fort Wayne, Ind., the other for Hamilton, Ohio,—in which this general idea will be carried out. Boilers will be on the ground floor, the turbine located directly overhead; thus the steam and exhaust runs will be short and direct, the initial steam coming up and the exhaust going down, as they should. The exciters are put on the generator shaft, thus eliminating separate exciting units; in fact, the stations will contain as little in the way of auxiliaries as possible. There will be some saving in building construction, considerable saving in ground space, and it would not be surprising if the whole station, including ground, were to show a reduction in first cost per kilowatt of 25 per cent. on the usual capital account of such properties.

AUTOMATIC CONTROL FOR LARGE DIRECT-CURRENT MOTORS

H. D. JAMES

THE use of motors for electric traction has done more for controller development than any other cause, though the pioneer work in automatic control was done with elevators and hoists. With large motors the manually operated drum controller is less desirable than an automatic controller. In the development of this latter method of control rapid advances have been made owing to the increasing use of motors for heavy electric traction and for heavy industrial work. A controller capable of handling a motor of 900 hp was completed and tested a few months ago. The bringing out of apparatus capable of handling such large motors marks a new departure in the construction of automatic reversing controllers. The writer feels

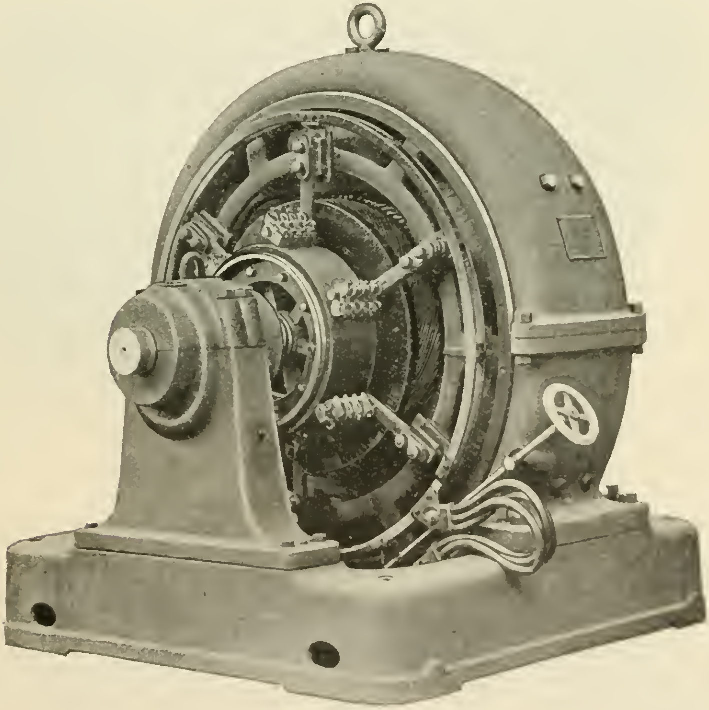

FIG. 1

therefore that a description of this controller and its behavior under test will be of general interest.

MOTOR

The motor referred to is of 600 hp nominal rating at 500 volts and capable of developing 900 hp intermittently. The armature or revolving part weighs approximately 12 000 pounds, is 48 inches in diameter and revolves 270 r. p. m. at full load and 500 r. p. m. at no load. The field is compound wound and the series coil remains in circuit at all times. The general appearance of this motor is illustrated in Fig. 1.

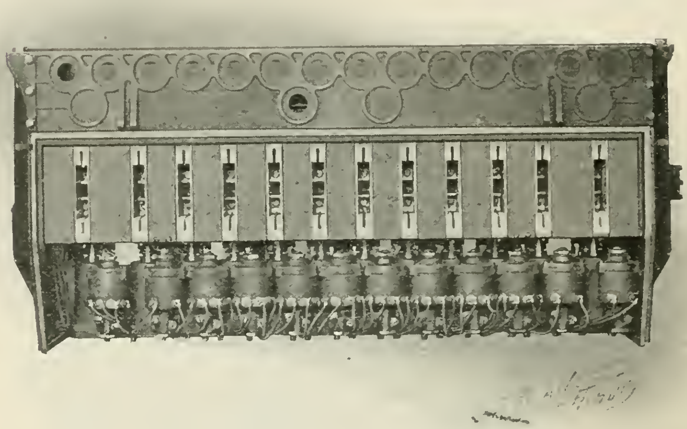

FIG. 2—12 UNIT SWITCH GROUP, COVER REMOVED, SHOWING CIRCUIT BREAKERS.

CONTROLLER

The controller proper is operated by compressed air. The valves to the air cylinders are controlled by electromagnets supplied with current from a separate low voltage circuit.

Each valve is held by a spring in the position which cuts off the air pressure from the cylinder and connects it with the exhaust. When the magnet is energized the exhaust is closed and air admitted to the cylinder. Thus air pressure compresses a heavy spring and closes the circuit breaker, or in the case of the reverser, rotates it to the opposite position.

The main part of the controller consists of twelve electrically operated circuit breakers supplied with powerful blowout magnets and removable arcing tips (see Figs. 2 and 3). Two of these circuit breakers are connected in parallel to the motor on each side of the line when the controller is in the full-speed position. The switches in this group are used for disconnecting both sides of the line from the motor and for cutting out the resistance in the armature circuit. The cutting out of this resistance is controlled automatically so that the motor will accelerate at the maximum current for which the controller is set. The main controller is operated by a small master controller or switch. If it is desired to run on any of the resistance notches the operator can do so by manipulation of the master switch. If the master switch is placed in the running position and left there the motor will accelerate at the maximum current.

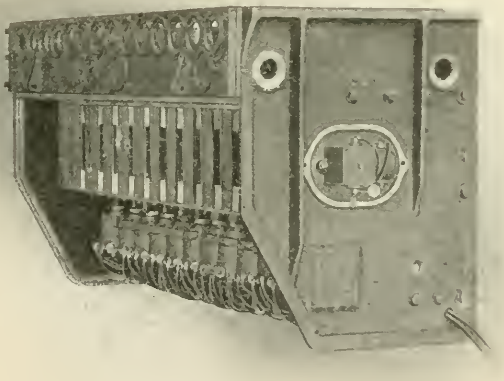

FIG. 3—UNIT SWITCH GROUP, COVER REMOVED, SHOWING CIRCUIT-BREAKERS

The reverse switch, (see Fig. 4), is mounted in a separate frame and so arranged that no current is broken by its contacts. It also is operated by means of air cylinders controlled by electrically operated valves. Compressed air is likewise used to operate the friction brake and clutches, the air being controlled by the same electro-pneumatic valves which are used on the controller. All parts of this controller are protected from moisture and dirt by means of sheet iron covers.

SAFETY DEVICES

The operating coil of a small relay switch is connected in series with the shunt field of the motor (see diagram, Fig. 5). The contacts of this switch are connected in series with the low-tension operating circuit. This circuit controls the electro-pneumatic valves at such a point that should the shunt field of the motor be opened the switch will open the operating circuit and the controller will automatically return to the off position. This effectually prevents the motor from running away in case the shunt field circuit is accidentally opened.

The operating circuit passes through an interlocked device on the brake cylinder so that the motor can not be connected to the line until the friction brake is released. To guard against an accident due to cross-connection or ground on the wires between the master switch and the controller the connections are so arranged that it requires the damaging of three of these wires to prevent the operator from opening the circuit breakers and bringing the motor to rest.

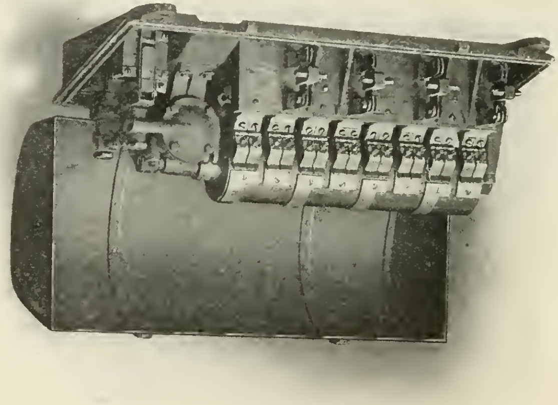

FIG. 4—REVERSE SWITCH, WITH COVER DROPPED.

Two different devices are provided to prevent the motor being reversed in such a manner as to cause a short-circuit on the line.

An over-load device is provided in duplicate. This device consists of an automatic trip which operates when the current reaches a predetermined limit, and opens the circuit to the air-valve magnets, thus bringing the control mechanism automatically to the off position. This trip is locked in the off position and provided with a reset coil so that by closing an auxiliary switch this overload device is returned to its normal position and the controller can again be operated in the usual manner.

TEST

Upon the completion of this apparatus it was connected up and the different devices described thoroughly tested. It was found that in cases of emergency it was possible to reverse the motor while running at full speed with only the starting resistance in series with the armature. When the reverse

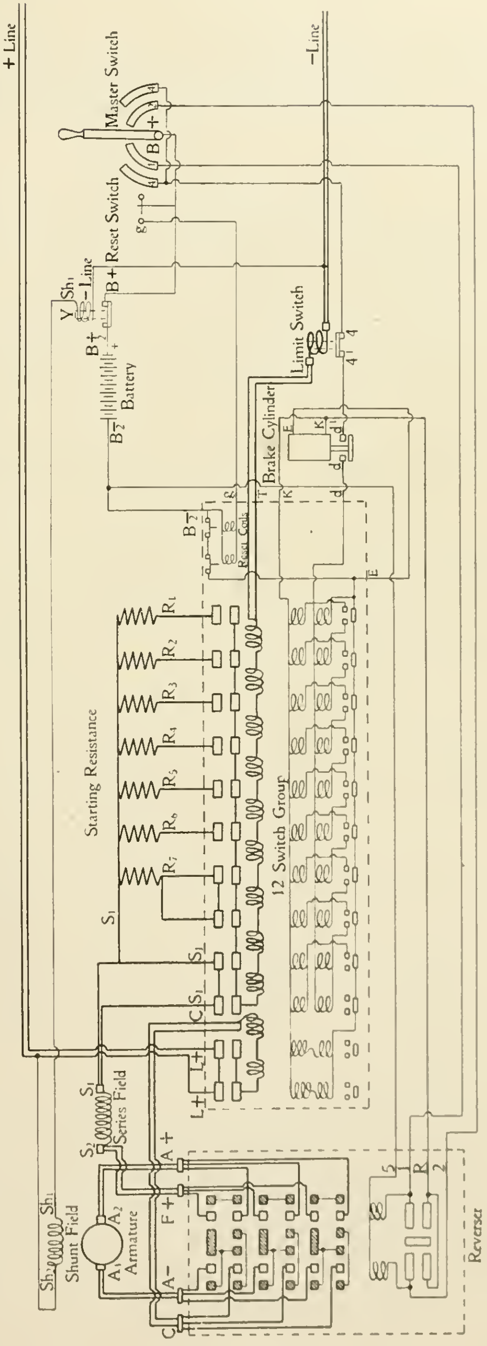

FIG. 5

circuit was closed there was an instantaneous flash at the motor brushes but no tendency to "buck over" and the armature came to rest and accelerated in the opposite direction in six to seven seconds.

GENERAL

The electro-pneumatic system of control has already won its way into favor for railway work, but up to the present, few realize its advantages for the control system of large motors. A pressure of several hundred pounds is available for closing the contacts of the current breaker which permits the use of a powerful spring for opening the breaker, thus causing a quick break of the arc, which reduces the burning and prevents the breaker from sticking. The air valves can be controlled by very small magnets wound for low voltage. This materially reduces the liability to trouble with these circuits and there is practically no burning on the contacts of the master-switch interlocks. The power required to operate these valves is so small that the pilot wires need be only large enough for mechanical strength. This low voltage circuit can also be used for signal purposes when the master switch is located at a distance from the machine.

A strong point in favor of this system is the facility with which friction brakes and mechanical clutches can be operated and controlled with compressed air by using the same magnets and valves which are used on the circuit breaker. The pressure of the brake or clutch can be varied through wide limits by manipulating the control valve. As compressed air is used in many industrial establishments it is often available and needs only to be connected up through a strainer and drip cup. When compressed air is not available a small tank and compressor can be installed. These compressors are made up in convenient direct-connected units and controlled by automatic pressure regulators.

The low voltage control circuit can be supplied from a small motor-generator set; or storage batteries in duplicate, one set being charged while the other is in use. These batteries are put up in very convenient shape and are easily handled.

Renewable arcing tips are provided for the circuit breakers, so that the whole outfit is easily kept in repair.

THE ELECTRIFICATION OF THE LONG ISLAND RAILROAD*

O. S. LYFORD, JR.

Electrical Engineer, Westinghouse, Church, Kerr & Co.

OVER 780 000 horsepower in power station equipment for electrical operation has been installed, or is planned for use, in New York City and its immediate vicinity.

For each unit of generator capacity there is, of course, a greater capacity of transformers, converters, motors, lamps, etc., and back of the generators, are the engines, boilers, condensers, etc., and around these suitable buildings.

Of this total, over 650 000 horsepower is for railway purposes, and it is interesting to note that this use of power on such an enormous scale has all been developed in about fifteen years.

In 1890 there were about 3 000 small surface cars in use on Manhattan Island, with about 18 000 horses to draw them. I presume the total number of horses used for traction purposes in what is now known as the metropolitan district did not then exceed 35 000.

In that year the first electric traction on Manhattan Island appeared in the form of storage battery cars operated experimentally in Madison Avenue. Since then the cable car has come and gone; compressed air motors have also been tried and abandoned, leaving the entire field of urban traction to electricity.

The experience with the operation of single surface cars and later with trains on the elevated lines, demonstrated the feasibility of extending the utilization of electricity to the propulsion of the heaviest trains of trunk lines, and as soon as this point is reached we find the great railroads preparing to adopt this means of locomotion.

The electrification of the Long Island Railroad presents the first transformation of a regular steam road to electric traction. Branch lines of minor importance have been operated electrically, but this is the first extended electrification of the main tracks.

It is one thing to provide simple passenger service on independent lines on a schedule which varies little during the year. It is quite another thing to provide for a service over eight radiating and interconnected lines where traffic varies at different times of the year and where limitations of right of way, terminals, yards, signal operation, handling of baggage and express matter, etc., all have to be considered. All of these things have a bearing on the selection of car equipment and the means of delivering power to this equipment.

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*This article is part of an illustrated lecture before The Electric Club presenting many of the general problems encountered in this notable installation.

Again it is one thing to plan for such a system as the Manhattan or Subway roads in New York, where practically the full limit of track capacity is to be provided for at once, and it is quite another thing to lay out a system sufficiently flexible so that it may grow with great rapidity and provide for the future without burdening the initial service with too much unemployed investment. The suburban system of the Long Island Railroad probably exemplifies all of the problems which are liable to arise in undertakings of this character.

A number of special conditions have to be met, some of which are common to all trunk lines and some of which are peculiar to this project. Steam equipment must be handled over the same tracks. There is an interchange of traffic with other roads. The train operation is in subways, on the surface and on elevated tracks. The summer traffic to the beaches is extraordinary in volume, and there is a race track service which is not only difficult to handle because it is shifted from point to point, but because the trains are quickly loaded after the races are over and move out from the station on close headway, resulting in heavy peak loads on the system.

The widely differing character of the passenger service calls for trains of from two to ten cars in length. The rapidity of traffic expansion is indicated by the fact that the initial service provided for the year 1906 is four times the 4th of July service in 1902.

Such an undertaking imposes most rigid requirements, a few of which may be mentioned for illustration.

Public Safety. This involves proper guards and substantial supports for all conductors, the most perfect forms of automatic safety devices and most substantial designs of equipment.

Safety of Employes. The employes in the buildings and on the cars and especially employes that have to do with the maintenance of the conductors must be safeguarded against their own mistakes as well as against the wrong operation of the equipment.

Continuity of Service. The extended territory over which electric service is carried on, and the nature of this territory involves unusual possibilities of disturbance to the operation. These necessitate unusual precautionary measures.

Prompt Action in Emergencies. The convenience and safety of the public, as well as the maintenance of the earnings of the railroad, require special attention to the means of communication between various points of the system and utmost convenience in the arrangement of apparatus so that emergencies can be met with the utmost promptness and service resumed.

Permanence. The extent of the project and the character of the service warrant the adoption of most permanent types of construction.

Economy of Operation. Operating features affecting the amount of labor, supplies and repairs require careful consideration.

Highest Class of Construction. The nature of the undertaking warrants an installation of the highest class, and this must be accomplished at a minimum cost for such construction.

In a word such an undertaking calls for the latest and best engineering practice in every detail, and utmost diligence in construction. These are not new problems, but a project of this character presents them with unusual emphasis. Likewise the solutions described are not radically different from the best that have been adopted before, but they are more perfectly worked out and better harmonized than ever before. This involved an acquaintance with what others have done and are doing as well as extensive experience in all branches of engineering.

There is a distinguishing feature which is carried through the designs of all parts of the system, and that is the uniformity in the engineering. A detail inspection of such an installation as this usually discloses points of demarcation where the character of design changes. This is due to the fact that the work is done under sub-contractors and each contractor conforms as far as possible to his previous practice. In the present case, the civil, mechanical and electrical features of the entire installation have been designed by engineers of one organization, Westinghouse, Church, Kerr & Company, and most of the apparatus has been designed by the associated Westinghouse organizations that have worked together for years. Uniformity and general sufficiency result. For instance the devices for the protection of apparatus and employes in the power station correspond in character with the devices for the protection of property and the public along the right of way. The machinery and equipment have been designed with special reference to convenience of operation in an installation of this character, and the structures have been designed with a full knowledge of the operating characteristics of the equipment with the requisite facilities for proper attention.

Every detail is substantial, rugged and permanent in character. As far as possible the same general factor of safety has been applied throughout. The equipment and structures are fireproof to an unusual degree. The buildings and cars and their equipment, and to a large extent the transmission system itself contain no combustible material except what is necessary for insulation purposes.

The record-breaking pace of work which flowed out of united energies, was remarkable. The power station was constructed and ready for operation in 16 months; in 18 months 100 miles of track were electrified, 25 miles of conduit and 24 miles of pole line were constructed; 250 miles of high-tension conductors were erected, five sub-stations were built and equipped; 130 steel motor cars built and equipped, 85 trailer cars equipped, and the operation of the road begun. Other power stations of similar character have usually been twice as long in construction and other parts of the equipment have taken a proportionately long time.

PROTECTIVE APPARATUS

FOREIGN PRACTICE—CHOKE COIL PROTECTION

N. J. NEALL

FOREIGN usage of the choke coil as an element in protective apparatus has not lead to the development of any marked departures from the best American practice.

Strictly speaking, only two forms have been developed abroad, the spiral coil, shown in Fig. 1, the function and manipulation of which are obvious, and the Gola "lightning arrester." This device is really a choke coil in its function as it is placed in the line, and not between line and ground. By referring to Fig. 2 the following description of its operation will be understood.

Any static disturbance coming in from the line strikes a large shield-like body covering the main or melon-shaped body. These parts are of iron and are fastened to the apparatus by brass washers from which connection is made to a small coil of a few turns of insulated wire on an iron core connected to the large body. The device has a very sharp edge, opposite which at either side are placed horn-shaped carbon electrodes to carry the electrical disturbances off to earth. Connection is usually made here to a standard lightning arrester.

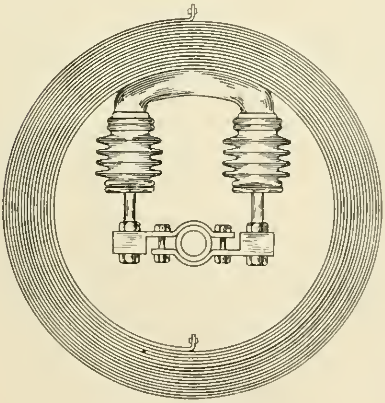

FIG. 1

It is claimed for this device, that while normally there will be no obstruction whatever to main current, high frequency disturbances such as those arising from lightning or of similar origin will be repulsed and thrown to earth over the discharge path.

The presence of the coil is supposed to create a magnetic field between the shields and the main drum, the brass or non-magnetic washers causing the field to line up radially between these parts. In addition, the difficulty presented by sharp turns to the passage of high frequency disturbances is taken advantage of by the peculiar shape of the drums and shields. It is claimed that a disturbance on reaching the device spreads out very rapidly from a small to a large cross-section and encounters so great difficulty in contracting again to reach the apparatus protected that it is easier to go to ground at the point of sudden change of cross-section. The magnetic field is supposed to assist in driving the disturbance to the edge.

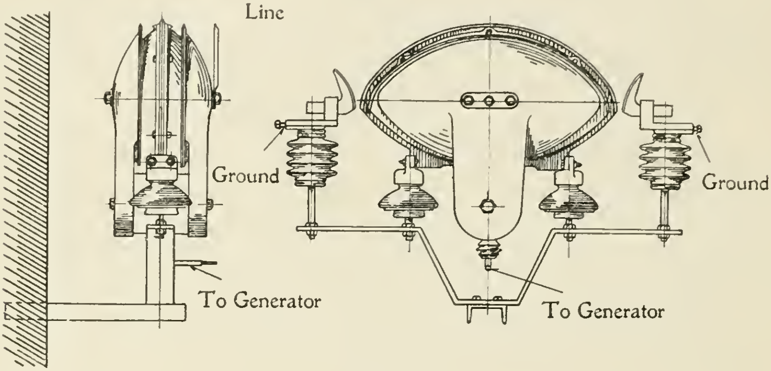

FIG. 2

The device was given a test under the same conditions described in a previous article for determining the protective power of a choke coil.*

It was found that the choking effect was exceedingly small, merely that of the coil used in its construction, and that even under ordinary tests the insulation of this coil would break down and destroy the small protective power which it might have afforded. It was not found possible to establish the other points claimed for its construction and the inference to be drawn was that it is not very efficient, and disproportionately large for the work it had to do.

Torchio in a recent paper before the A. I. E. E.† says:

"The device has been used in many places in Italy for the last two or three years. In many cases it has proved most effective, while in other cases the results have been indifferent."

Some of the best styles of American choke coil apparatus have also been adopted abroad.

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*See *The Electric Journal*, Vol. II, p. 609.

†See *Trans. A. I. E. E.*, October, 1905, p. 997.

"THE DURABLE SATISFACTIONS OF LIFE"*

PART OF AN ADDRESS BY CHARLES WILLIAM ELIOT

"FOR educated men, what are the sources of the solid and durable satisfactions of life? That is what I hope you are all aiming at—the solid, durable satisfactions of life, the satisfactions that are going to last and grow. So far as I have seen, there is one indispensable foundation for the satisfactions of life—health. A young man ought to be a clean, wholesome, vigorous animal. That is the foundation for everything else, and I hope you will all be that, if you are nothing more. We have to build everything in this world of domestic joy and professional success, everything of a useful, honorable career, on bodily wholesomeness and vitality.

"This being a clean, wholesome, vigorous animal involves a good deal. It involves not condescending to the ordinary barbaric vices. One must avoid drunkenness, gluttony, licentiousness, and getting into dirt of any kind, in order to be a clean, wholesome, vigorous animal. Still, none of you would be content with this achievement as the total outcome of your lives. It is a happy thing to have in youth what are called animal spirits—a very descriptive phrase; but animal spirits do not last even in animals; they belong to the kitten or puppy stage. It is a wholesome thing to enjoy for a time, or for a time each day all through life, sports and active bodily exercise. These are legitimate enjoyments, but if made the main object of life, they tire. They cease to be a source of durable satisfaction. Play must be incidental in a satisfactory life.

"What is the next thing then, that we want in order to make sure of durable satisfactions in life? We need a strong mental grip, a wholesome capacity for hard work. It is intellectual power and aims that we need. In all the professions—learned, scientific, or industrial—large mental enjoyments should come to educated men. The great distinction between the privileged class to which you belong, the class that has opportunity for prolonged education, and the much larger class that has not that opportunity, is that the educated class lives mainly by the exercise of intellectual powers and gets therefore much greater enjoyment out of life than the much larger class that earns a livelihood chiefly by the exercise of bodily powers. You ought to obtain here, therefore, the trained capacity for mental labor, rapid, intense, and sustained. That is the great thing to get in college, long before the professional school is entered. Get it now. Get it in the years of college life. It is the main achievement of college life to win this mental force, this capacity for keen observation, just inference, and sustained forethought, for everything that we mean by the reasoning power of man. That capacity will be the main source of intellectual joys and of happiness and content throughout a long and busy life.

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*Mr. Frank H. Taylor was requested to contribute to the first issue of the Journal for 1906. In response he commended to the Journal and its readers the address of President Eliot to the students of Harvard University, which appeared in this month's McClure's Magazine. The address is reprinted in slightly condensed form.

"But there is something more, something beyond this acquired power of intellectual labor. As Shakspere puts it—'the purest treasure mortal times afford is spotless reputation.' How is that treasure won? It comes by living with honor, on honor. Most of you have begun already to live honorably, and honored; for the life of honor begins early. Some things the honorable man cannot do, never does. He never wrongs or degrades a woman. He never oppresses or cheats a person weaker or poorer than himself. He never betrays a truth. He is honest, sincere, candid, and generous. It is not enough to be honest. An honorable man must be generous; and I do not mean generous with money only. I mean generous in his judgments of men and women, and of the nature and prospects of mankind. Such generosity is a beautiful attribute of the man of honor.

"How does honor come to a man? What is the evidence of the honorable life? What is the tribunal which declares at last—'This was an honorable man'? You look now for this favorable judgment of your elders—of parents and teachers and older students; but these elders will not be your final judges, and you had better get ready now in college to appear before the ultimate tribunal, the tribunal of your contemporaries and the younger generations. It is the judgment of your contemporaries that is most important to you; and you will find that the judgment of your contemporaries is made up alarmingly early; it may be made up this year in a way that sometimes lasts for life and beyond. It is made up in part by persons to whom you have never spoken, by persons who in your view do not know you, and who get only a general impression of you; but always it is contemporaries whose judgment is formidable and unavoidable. Live now in the fear of that tribunal—not an abject fear, because independence is an indispensable quality in the honorable man. There is an admirable phrase in the Declaration of Independence, a document which it was the good fashion of my time for boys to commit to memory. I doubt if that fashion still obtains. Some of our public action looks as if it did not. 'When in the course of human events, it becomes necessary for one people to dissolve the political bands which have connected them with another, and to assume among the powers of the earth the separate and equal station to which the laws of Nature and of Nature's God entitles them, a decent respect to the opinions of mankind requires that they should declare the causes which impel them to the separation.' That phrase—a decent respect—is a very happy one. Cherish 'a decent respect for the opinions of mankind,' but never let that interfere with your personal declaration of independence. I have said begin now to prepare for the judgment of the ultimate human tribunal. Look forward to the important crises of your life. They are nearer than you are apt to imagine. It is a very safe protective rule to live to-day as if you were going to marry a pure woman within a month. That rule you will find a safeguard for worthy living. It is a good rule to endeavor hour by hour and week after week to learn to work hard. It is not well to take four minutes to do what you can accomplish in three. It is not well to take four years to do what you can perfectly accomplish in three. It is well to learn to work intensely. You will hear a good deal of advice about letting your soul grow and breathing in without effort the atmosphere of a learned society, or place of learning. Well, you cannot help breathing and you cannot help growing; those processes will take care of themselves. The question for you from day to day is how to learn to work to advantage and college is the place and now is the time to win mental power And, lastly, live to-day and every day like a man of honor.

THAWING PIPES BY ELECTRICITY

WALTER M. DANN

ONE of the latest electrical appliances, which has made possible the application of electricity to an ordinary everyday service, is the thawing transformer. This useful piece of apparatus promises to replace to a great extent the present arduous methods of using a torch on frozen house piping, or of digging trenches and thawing frozen street mains by means of a bonfire or live steam. A short time ago the use of steam was hailed as a great advance over the primitive bonfire method, and now the economy and ease of operation of the electrical method is becoming generally recognized.

A comparison with the first contrivances used, illustrates the rapid advances made in the development of pipe thawing apparatus. The pioneer outfit consisted of several lighting transformers loaded on a wagon, together with an elaborate array of switches and circuit breakers mounted on a switchboard panel, the whole set weighing several thousand pounds. The results obtained with this bulky apparatus were highly successful and the way was prepared for a new application of electricity which has proved a source of revenue for the station man as well as a saving for the property owner.

The operating principle is simple enough, being merely an application of Ohm's law. The conditions of service have such a wide range that it is difficult to specify the proper voltage and current and the length of time required for any particular instance. In general, the current required will depend upon the size of the pipe and its depth below the surface. The voltage required will, of course, vary with the length of the pipe. A large pipe, whose resistance is low will take more current at a lower voltage than a small pipe, other conditions being equal. The length of time required to produce a flow of water will vary inversely with the square of the current. Instances are on record where rapid thawing with a heavy current has resulted in damage to the pipe at the points of contact or at couplings, so that it is usually safer to employ a moderate current for a longer period.

In the table on the next page are figures obtained in actual practice, showing the current, voltage and length of time required to produce running water in iron pipes of varying sizes and lengths.

Diameter in inches.	Length in feet.	Amperes.	Volts.	Time Required.
½	50	250	20	5 min.
½	70	300	16	15 “
½	100	150	20	45 “
¾	80	300	110	23 “
¾	100	135	55	10 “
¾	240	250	52	30 “
¾	380	300	30	10 “
1	45	140	220	17 “
1	250	500	50	20 “
1	600	60	50	1 hr.
1	700	175	55	5 “
2	20	2000	6	3 “
2	50	500	50	2 “
2	60	160	50	4 “
2	300	250	52	2 “ 30 “
4	800	300	50	3 “
6	400	800	110	2 hrs. 10 min.

The results tabulated show several marked inconsistencies which serve to emphasize the effect of varying conditions and the difficulty of prescribing set rules for the voltage and current which will be required. It will be noticed that in the case of two one-inch pipes of about the same length, the first one required 175 amperes for five hours, while the second one was thawed in one hour with about one-third as much current. The first pipe was embedded in solidly frozen ground, while the second one was possibly frozen for only part of its length. The results in the first instance show poor connections and insufficient copper in the secondary circuit. Experience seems to indicate that an e.m.f. of from 30 to 50 volts will meet most of the requirements imposed by the thawing of ordinary house piping, and that 500 amperes will in a reasonable time thaw almost any main up to six inches in diameter. A twelve-inch main may take as much as a thousand amperes.

The service conditions make it necessary that a thawing transformer be as compact and portable as possible. Furthermore, it must be both mechanically and electrically strong and rugged to withstand the severe conditions of rough weather, frequent handling and possible short-circuit. A small compact outfit weighing 100 pounds is illustrated in Fig. 1. The primary winding is arranged for connection to a 2 000 volt line. At the secondary terminals an e.m.f. of either 55 or 35 volts is obtained by means of the plugs and receptacles mounted in the top of the transformer. The secondary winding will carry a current of 100 amperes for half an hour without overheating. To protect itself against injury in the event of accidental short-circuit, the transformer is designed with a high magnetic leakage so that with heavy currents the secondary voltage decreases very considerably. As a consequence the current on short-circuit is limited, so that the transformer may operate on short-circuit for ten or fifteen minutes without injury. This usually undesirable falling off of voltage under load, or "drooping characteristic," is thus used to advantage.

For thawing large mains, a transformer built along the lines of the small one just described would be bulky and unwieldly, since more capacity is required for a greater length of time. A satisfactory outfit for heavy duty consists simply of a standard lighting transformer with some means of regulating the secondary current. A choke coil used in series with the transformer will not only give the desired variation of current without the loss involved in a dead resistance, but will also afford the protection against injury on short-circuit which was obtained in the small transformer by a high magnetic leakage.

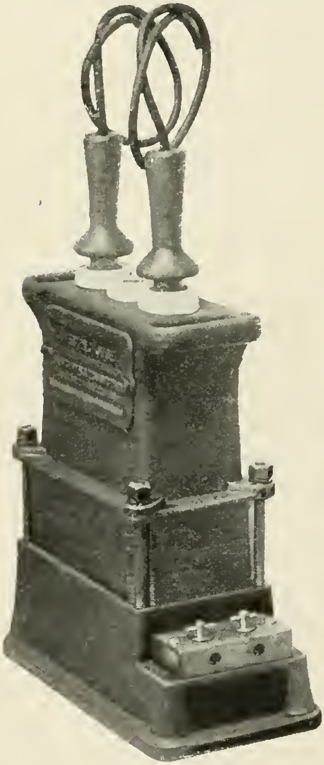

FIG. 1

A choke coil designed for use with a 2 100 volt lighting transformer is illustrated in Fig. 2. It consists of a single winding, several points of which are connected to receptacles mounted in the top of the case. Its choking effect is varied by an adjustment of the plugs in the receptacles. The choke coil and the transformer may easily be moved from place to place on a truck or wagon, as the weight of the former is only 200 pounds. An objection to the use of a choke coil might be raised on the score that the transformer is not complete in itself. Opposed to this objection, however, is the decided advantage gained by the unrestricted use of any available transformer having the proper ratio and of from 15 to 25 kw capacity. This advantage will be appreciated by the station manager for his investment will end with the purchase of the choke coil, and the transformer may be one which is used at other times on ordinary lighting loads.

In thawing by electricity, it is important that the apparatus be placed as close as possible to the frozen pipe. The secondary winding is connected to the pipe in such a way that the frozen portion is included between the two contacts. Resistance in the secondary circuit is obviously undesirable, so that unnecessary length of cable should be avoided and good contacts at the pipe are highly important. In thawing house piping, one secondary lead is usually connected to the house faucet and the other to a hydrant or to a faucet in an adjacent house. In thawing street mains, connections are made to two hydrants or fire plugs, or to one hydrant and the pipe beyond the frozen part, as shown in Fig. 3. Too much emphasis cannot be placed upon the necessity of avoiding unnecessary resistance in the low voltage circuit and failure may often be turned into success by making all contacts more secure and by adding more copper to the secondary circuit.

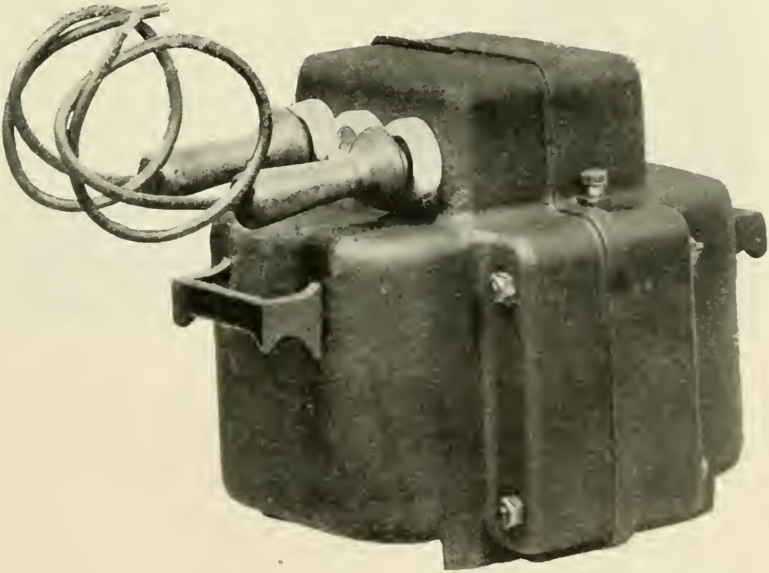

FIG. 2

An idea of the cost of thawing by electricity may be gained from the data contained in the table, though different conditions may require expenditures of energy quite different from those included in the list. The cost to the customer is sometimes based upon a minimum charge for the first hour with a fixed charge for each additional hour, but more often it is represented by a fixed charge for the operation, which varies in different localities from five to fifteen dollars.

When considering the inconvenience and expense of laying open streets and sidewalks to get at a frozen water main, it is not hard to see the advantages of the electrical method. It may be of interest to cite a case showing the value of a thawing transformer. In two successive winters of exceptional severity a six-inch water main became frozen for quite a distance at a point where it was carried over an arched stone bridge. It was thawed out the first time in the old way by a force of laborers who completed the work in six weeks. The following year the thawing transformer accomplished the operation in six hours, including the time of connecting up the apparatus.

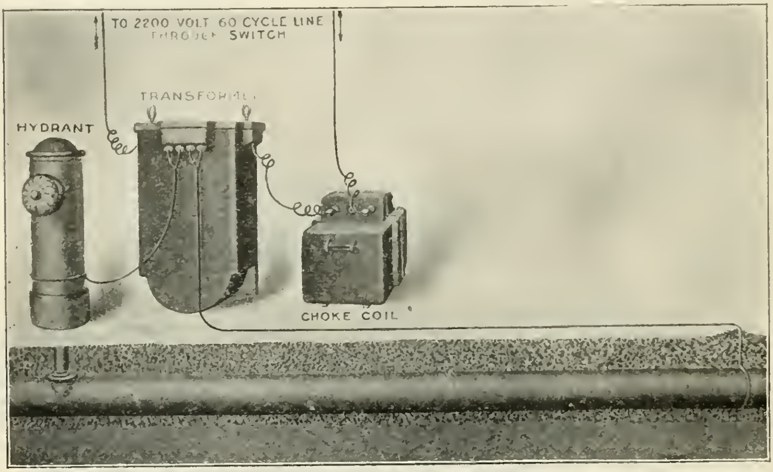

FIG. 3

THREE-PHASE—SINGLE-PHASE TRANSFORMATION

A CORRECTION OF A MISAPPREHENSION

CHAS. F. SCOTT

"It is desired to take three-phase current from the power-house bus-bars and convert it to single-phase current without unduly unbalancing the three-phase system. A sketch of the transformer connections proposed is shown in Fig. 1. Certain engineers advise that this will produce unbalancing of the three-phase system. Why is this so? Is there a possible rearrangement of connections which would obviate this result?"

IN connection with various methods, which are from time to time proposed for operating a single-phase circuit from a three-phase generator, there is a general principle which is universally applicable. In a normally operating symmetrical three-phase system the flow of energy is uniform. It is comparable mechanically to the continuous flow of energy through the instrumentality of a belt or from an engine where two or more cylinders with connecting rods are connected to a common shaft, their cranks being set at the usual angles. The single-phase system, on the other hand, has as its characteristic, an intermittent flow of energy. At certain moments the energy is zero. It is therefore impossible to convert from three-phase to single-phase and continue the normal operation in both systems unless there be some provision for storage of energy, such for example, as a rotating armature, which may be driven by a three-phase current and deliver single-phase current. The armature receives energy at a uniform rate and gives out energy at a periodically varying rate. The excess energy received during alternate intervals is stored in the form of mechanical energy in the armature; in the intermediate intervals it is delivered to the single-phase circuit. In this manner the average energy of the single-phase system is equal to the uniform energy of the polyphase system. Such a means of storing energy, however, is not found in ordinary transformers.

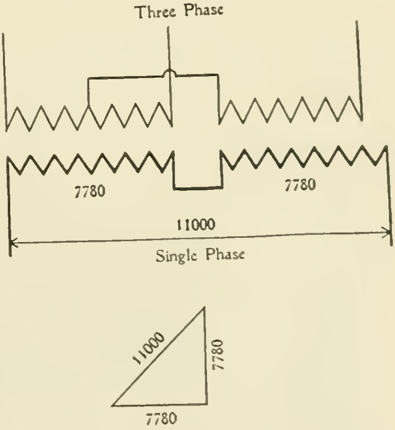

FIG. I

The foregoing consideration is a conclusive answer to the proposition that single-phase power can be taken by means of ordinary static transformers from a three-phase system without unbalance.

In the diagram representing the ordinary three-phase two-phase transformation by means of two transformers, the two secondary windings, which ordinarily deliver two-phase current, are in this case connected in series for supplying a single-phase circuit. The currents in the two windings must therefore be alike in phase, instead of differing by 90 degrees, as in a normal two-phase circuit. The electromotive forces on the individual secondary coils still differ in phase by 90 degrees. The currents which would flow through resistances, connected respectively to the individual coils, would likewise differ in phase by 90 degrees. But, when a resistance is connected across the two coils in series the same current will flow through both coils and its phase will be midway between the phases of the currents which the coils would produce if acting independently. It follows, therefore, that the phase of the "single-phase current," which is delivered by the two secondary coils in series lies between the phases of the electromotive forces, i. e., the maximum value of the current lags behind the maximum value of the electromotive force in one of the coils and leads that on the other coil. Hence the resultant current is a lagging current in one transformer and a leading current in the other.

The current in a primary winding of a loaded transformer has its maximum and zero values at practically the same instant as the current in the secondary. In the transformer which has a tap from the middle of its primary winding the current in this winding is the resultant of two components; one is the primary current, which produces secondary current in this transformer, and the other is the current which is received from the other transformer. As this current divides and flows equally from the center through the two halves of the winding in opposite directions around the core, it produces no effect upon the secondary. In normal three-phase two-phase transformation, the two components in each half of the winding differ in phase by 90 degrees. When, however, the final secondary circuits are connected in series, these two component currents are of one phase. The current which enters at the middle point of the primary divides and flows one-half in the same direction as the primary current, and the other half in the opposite direction from the primary current in this winding. Hence the resultant current is found by direct addition in one-half and subtraction in the other half. The result is that the current in the three wires from the three-phase generator is single-phase currrent, one wire constitutes one side of the circuit and the other two wires carry the return current. The three-phase generator is, therefore, badly unbalanced.

WINDING OF DIRECT-CURRENT ARMATURES

A. C. JORDAN

THE 38B type of armature described in the December issue of the JOURNAL is one that has been in use for a number of years, and has stood the test of actual service. Many improvements, mostly in details of construction have, however, been adopted in later types of armatures.

The 101B armature is a typical style of the more recent designs of railway armatures. A detailed description will be given of this armature with especial reference to the points of difference between the 38B already described and the 101B.

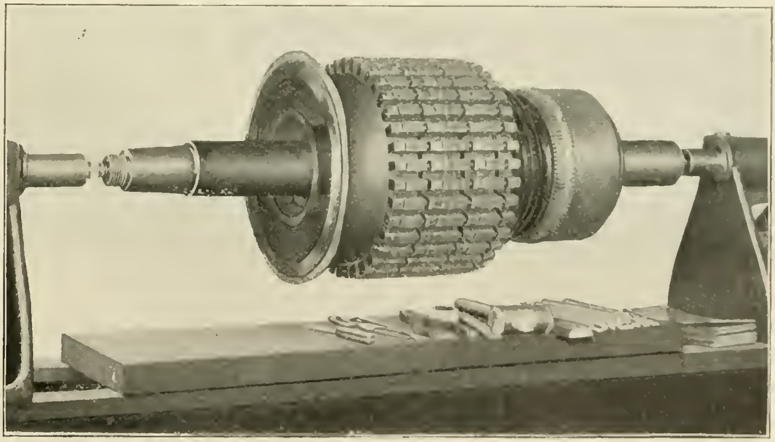

FIG. 1—INSULATED CORE

THE CORE

In the 101B motor armature, the punchings are assembled on a cast iron spider, and between end plates of cast iron. The spider is pressed on the motor shaft and keyed in place. This is a great improvement over assembling the punchings directly on the shaft, as the shaft may be removed without disturbing the core, windings, or commutator. The end plates are extended on each end to form a support for the coils, and on the pinion end the end plate has a flange or end bell to protect the ends of the coils. The coil supports on each end are first painted and then insulated with several layers of treated cloth paper. On each end where the coils are to rest this insulation is covered with adhesive tape. See Fig. 1.

WINDING.

The ends of the laminations and the tape on the end supports are given a coating of core paint.

In winding this armature, pieces of oiled duck and friction cloth are used in the insulation. Part of the strips are covered with friction cloth as in Fig. 2a. Then the friction cloth is folded over the duck, making a complete strip as shown in Fig. 2b. These strips are paraffined on both sides to keep them from sticking to the coils.

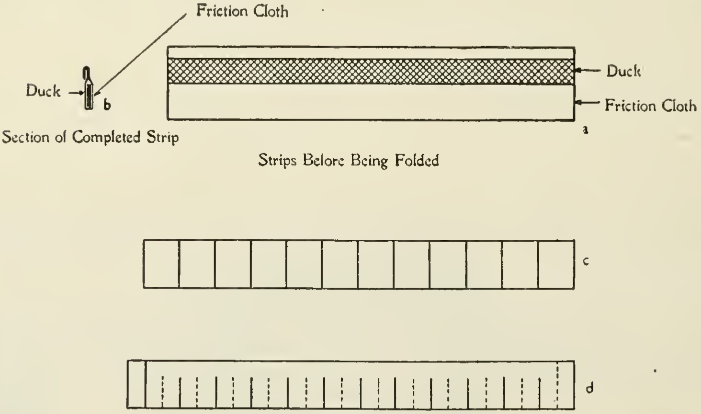

FIG. 2—FRICTION CLOTH AND DUCK STRIPS

Other pieces of duck are cut as shown in Fig. 2c. Fig. 2d shows two pieces overlapped ready to place in the winding.

There are 37 slots in this armature and 37 coils. Paraffined paper cells are used. The throw of the coil is 1 and 10. The leads come from the bottom of the coil. The lower leads are taped and bent, and the upper leads are bent over the edge of the coil and outward. The pieces of friction cloth containing the duck strips are placed in each end of the coils, as shown in Fig. 3.

Pieces of duck are placed over the lower leads and under the ends of the coils.

The tops of the coils are driven down so as to hold the strips in place. As each coil is put into place the strips must be pulled through the coil and the lower leads placed under the duck strips at the end. Cells are used in the armature similar to those in the 38B armature. After the coils are all in place and tested the cells are cut off about a quarter of an inch above the iron.

WEDGING

The coils in the armature are held in place by retaining wedges of hard fiber. These wedges slide in grooves punched in the armature teeth. All the wedges are first driven into the slots about four inches, and then a piece of fullerboard, wide enough to extend over the ends of the coils, is forced under the wedges and against the core. This is to protect the ends of the coils while wedging. The wedges are then driven flush with the rear ends of the core by the use of the wedging tool and mallet already described. Fig. 4 shows a view of an armature with part of the wedges in place.

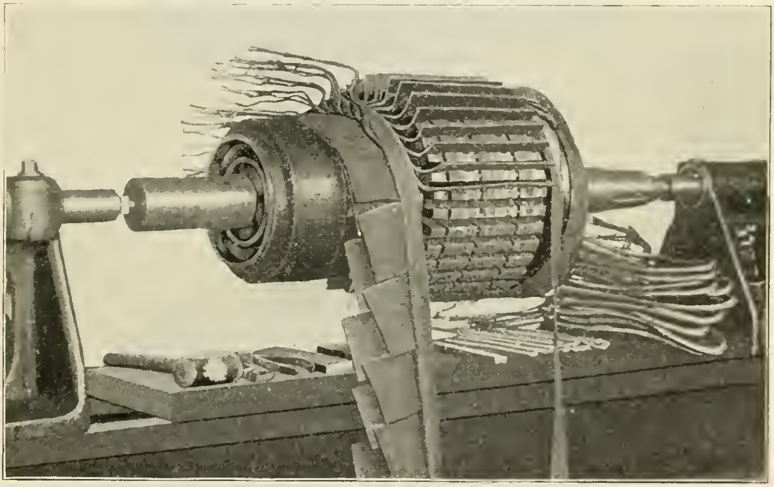

FIG. 3—FIRST TEN COILS IN PLACE

After the wedging is completed the armature is given a second test for grounds. The strips of duck are fitted back over the front ends of the coils and taped in place and the lower leads bent back over the duck. The armature is then given a coat of insulating paint and is ready to have the leads connected to the commutator.

CONNECTING

The only way in which the connecting of this armature is different from the 38B, is in the insulation of the ends of the coils. This is shown in Fig. 4.

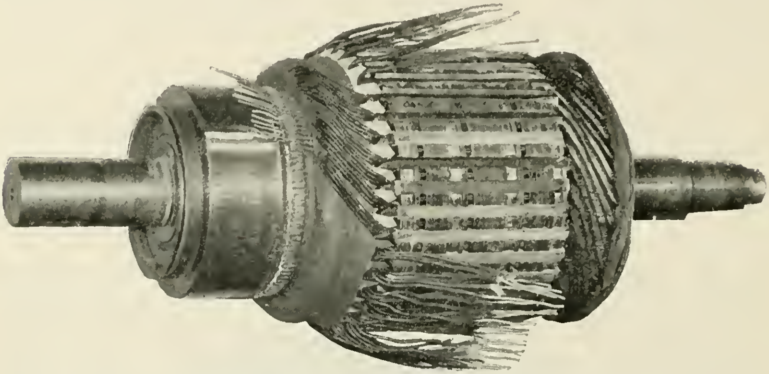

FIG. 4—ALL OF THE LOWER LEADS AND SEVERAL OF THE UPPER LEADS CONNECTED TO THE COMMUTATOR

BANDING

The banding differs in several details from that of the 38B.

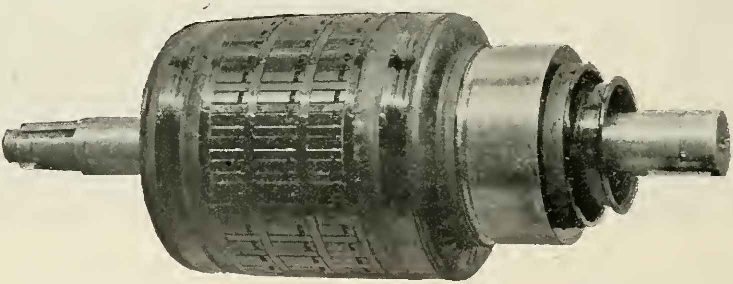

FIG. 5—COMPLETED ARMATURE

The bands on the core are in grooves in the laminations. The end bands are much wider. The ends of the coils at both ends are nicely covered with duck and the bands are placed over this. This keeps all dust and dirt out of the windings. The completed armature is shown in Fig. 5.

TYPE S ARMATURES

These armatures are used for constant speed, constant voltage work.

CORE

The core for this type of machine is usually assembled on a spider and provided with slots for ventilation. A fullerboard ring

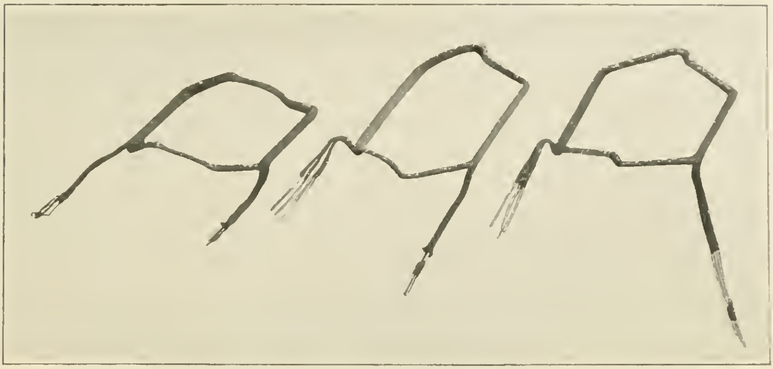

FIG. 6—VIEWS OF DIFFERENT COILS SHOWING HOW THE LEADS ARE BENT

is placed over the end plate on the commutator end, in order to keep the leads from touching the end plate. Both ends of the core are then painted with core paint.

WINDING

A special coil shown on the left side of Fig. 6 is used. This coil is shorter than any of the others shown, and thus the overall dimensions of the armature are shorter.

The inside ends of the coils on the commutator end are painted with an insulating compound. After the armature is wound, tested and wedged, the ends of the winding are trued, both on the top and the ends of the coils. The tops of the coils on the commutator end

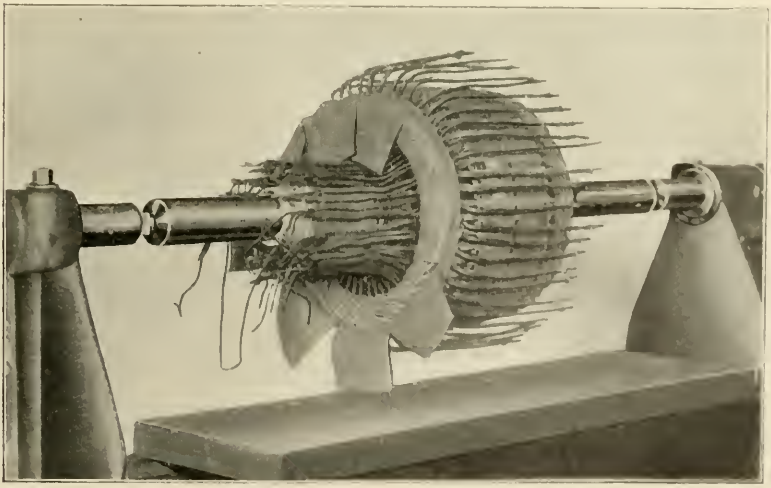

FIG. 7—FRICTION CLOTH USED INSTEAD OF A BLANKET

must be such a distance from the shaft that after the insulation is on the coils, and the top leads are brought over the front of the winding, the leads will be level with the top of the core. Layers of friction cloth are wound around the front end of the coils and layers of black tape over this next to the leads. The friction cloth must be long enough to fit tightly over the ends of the coils and underneath as far as the bottom leads. The friction cloth cut ready for use in insulating the ends of the coils from the leads is shown in Fig. 7. The lower leads are then bent back as in the description of the No. 38B railway motor.

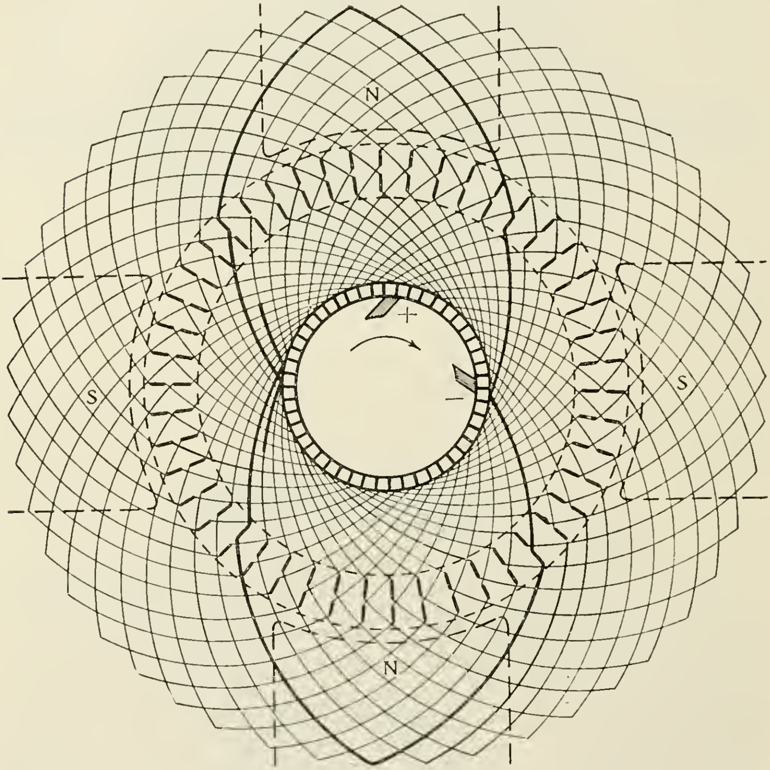

FIG. 8—TWO-CIRCUIT, PROGRESSIVE, WAVE WINDING FOUR POLES, 47 SLOTS, 47 BARS, 47 COILS, ONE TURN PER COIL, TWO COILS PER SLOT

CONNECTING

These armatures are connected in a manner similar to those already described.

BENDING AND TAPING LEADS

The leads are brought out of the sides of coils either at the top or at the bottom. If the leads come from the bottom, they are bent down and out. The top leads are bent back over the edge of the coil and outward.

Where the leads come from the top of the sides of the coil the lower ones are bent over the edge of the coil down and out. The upper ones are left as they are, straight out. Fig. 6 shows three different types of coils with leads bent.

Upper leads are never taped except in the case of an idle coil, so the following applies only to lower leads.

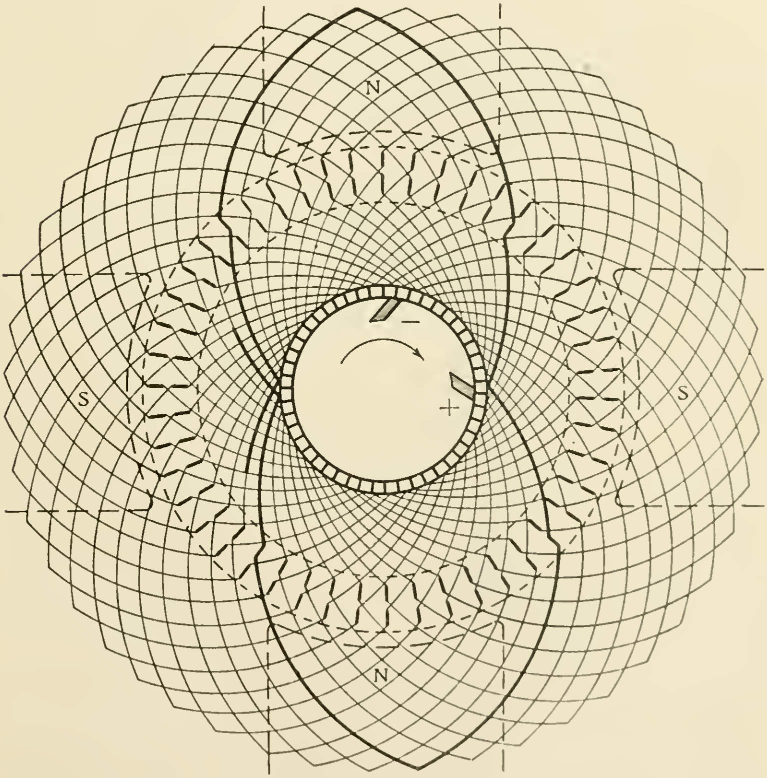

FIG. 9—TWO-CIRCUIT, RETROGRESSIVE, WAVE WINDING, FOUR POLES, 47 SLOTS, 47 BARS, 47 COILS, ONE TURN PER COIL, TWO COILS PER SLOT

Coils with single leads do not have the leads taped at all. Neither do coils with two leads when the number of commutator bars is equal to the number of slots in the core, because the two leads are in parallel, and both belong to the same bar in the commutator.

Coils having two leads which are to be placed in different bars have the outside lead taped with white tape, and then both taped together.

When a coil has three leads, the middle one is taped black, the outside one white, and all three bound together with white tape.

A coil with four leads is taped similarly to the coil with two leads, taping the two outside leads as one, and finally taping all together.

A coil with six leads is taped as a coil with three leads, taking two outside and two inside leads as one, as they are to be in parallel.

A coil with eight leads is taped similarly to a two-leaded or four-leaded coil, taping the four outside first.

A coil with nine leads is taped as a three-leaded coil, treating the three middle and three outside ones each as one lead.

The coils are taped in this manner so that the winders may know which are outside leads, which are middle leads, and which are inside leads.

When there is an idle coil in an armature the lower leads of the idle coil are taped their entire length, and a small piece of white tape wound around the upper leads.

GENERAL CONSIDERATION OF ARMATURE WINDINGS

Almost all armatures are lap or wave wound, with progressive or retrogressive windings. Figs. 8 and 9 show a progressive, four pole, wave winding and a retrogressive, four pole, wave winding. It will be seen that a progressive winding continues around the commutator in a clockwise direction and the retrogressive winding proceeds around the commutator in a counter clockwise direction. The difference in the operation of the two windings is that a motor wound with a retrogressive winding, runs in the opposite direction from one that is wound with a progressive winding. If used as a generator, the polarity of the terminals is reversed. Whether an armature is to be wound progressive or retrogressive is determined by the throw of the coils and the position of the short-circuited coil.

Take for example, a four pole, wave wound armature having 41 slots. Throw of coil, 1 and 9, one lead per coil, 41 commutator bars, progressive wound.

From the formula:—$C = ny + \text{or} - 2$.

where C=total number of conductors (Assuming one turn per coil),

where n=to the number of poles,

where y=average pitch.

To find C multiply the number of leads coming from any slot by the number of slots. If the armature is to be progressive use minus 2 in the formula, if it is to be retrogressive, plus 2 is used.

In this armature we have $C=82$, $n=4$.

$$\text{Then } 82=4y-2$$

$$y=21, \text{ average pitch.}$$

As the throw of the coil is 1 to 9, conductor No. 1 in slot No. 1 connects to conductor No. 18 in slot No. 9. The back pitch is the number of conductors between these two, and is 17 in this case. The front pitch is the number of conductors between conductor No. 18 and the one it is connected to on the commutator. It is found by adding the difference between the back pitch and the average pitch to the average pitch. This makes the front pitch 25. A winding table may be constructed by first adding back pitch and then front pitch to the number of the conductor where the winding is started, beginning with 1 in slot No. 1, as follows:

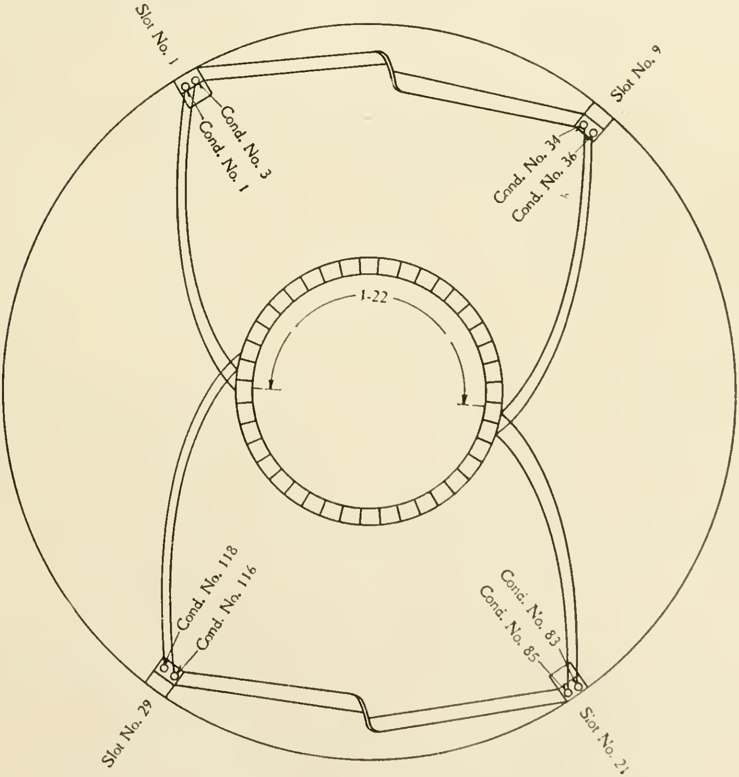

FIG. 10—PROGRESSIVE WAVE WINDING, FOUR POLE, TWO COILS CONNECTED

Commutator throw $\left[\frac{41+3}{2}=22\right]=1-22$.

Commutator bar	Conductor	Conductor
1	1	18
22	18	43
2	43	60
23	60	85

and so on around the armature. Fig. 10 shows two coils connected on this type of armature.

To wind this armature retrogressively proceed as follows:

$C=ny+2$, $y=20$.

Back pitch 17, average 20, front pitch 23.

Commutator throw $\left[\frac{41+1}{2}=21\right]=1-21$.

Commutator bar	Conductor	Conductor
1	1	18
21	18	41
41	41	58
20	58	81

and so on around the armature.

Fig. 11 shows two coils connected on this type of armature.

The following is an example of an armature slightly different from the one just given:

Four pole, progressive wound, 49 coils, 49 slots, throw of coil 1 and 12, four leads per slot, 97 bars.

Substituting in the formula: $C=ny-2$.

$196=4y-2$

$y=49\frac{1}{2}$, average pitch.

Since a fraction in the pitch means a fraction of a slot, which is not possible, a fewer number of conductors must be used. With 194 conductors,

$C=ny-2$

$194=ny-2$

$y=49$ average pitch.

If 198 conductors had been tried, then the average pitch would be 50. As the slots are completely filled, two extra conductors cannot be added, so the leads from the idle coil are cut off and insulated and the coil left in the slot for mechanical balance.

With throw of 1 and 12 the back pitch is 45, the front pitch 53, and the average pitch 49.

Commutator throw $\left[\frac{97+3}{2}=50\right]=1—50$.

The following example is a rather peculiar case, as the back average and front pitch are all the same:

Armature with three leads per coil, 37 slots, 37 coils, throw of coil 1 and 10, 111 bars, retrogressive winding.

$C=222 \quad 222=4y+2 \quad y=55$

Back pitch 55, average pitch 55, front pitch 55.

By the same methods used in the above example, winding tables may be constructed for any desired number of leads.

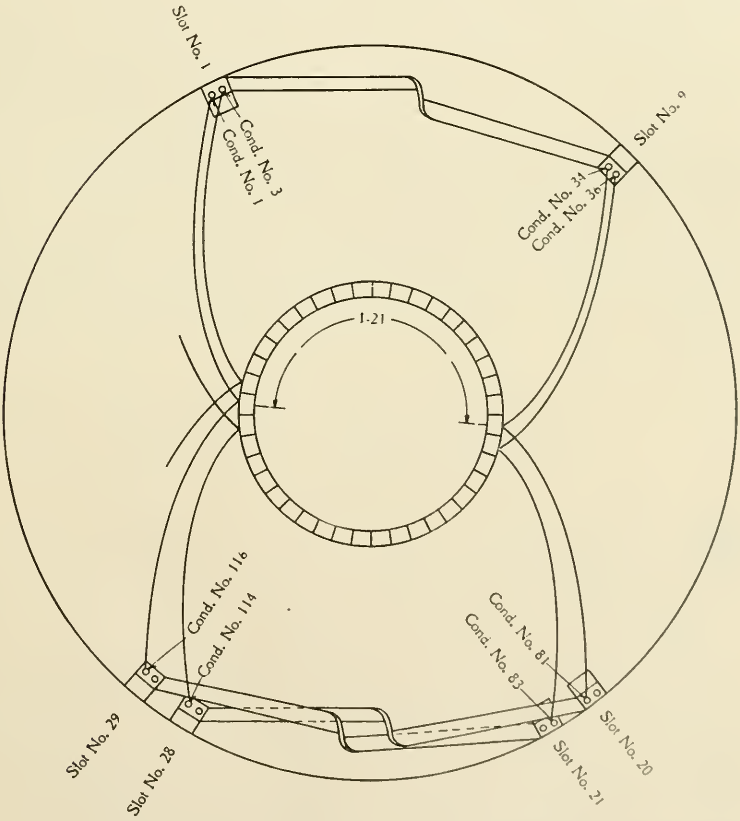

FIG. 11—RETROGRESSIVE WAVE WINDING, FOUR POLE, TWO LEADS AND TWO COILS CONNECTED

If the number of bars in the commutator is the same as the number of slots in the armature, and if there is more than one lead from each side of the coil, the leads on the same side are to be in multiple, and should be connected as one lead.

When the number of bars is twice the number of slots, two or more coils are assembled in a cell. In such cases the leads on each side should be uniformly separated into two divisions, if there is more than one lead in each division. Such leads are to be in multiple, and should be connected as a single lead to the commutator.

When the number of bars in the commutator is three times the number of slots, there are three or more cells assembled together. The leads on each side should be uniformly divided into three divisions and each division connected as one lead.

Sometimes there is an idle bar in the commutator. This is caused by using a special coil and winding with a standard commutator. This occurs chiefly in armatures wound with strap or bar copper. The idle bar is used so that the leads from the idle coil may be carried out to the commutator necks to avoid the crowding of the leads that would occur in connecting them to the commutator if the bar was left out. The bottom of the slot in the commutator neck is filled with "dummies," and the top lead or leads belonging to this bar are soldered to the other leads coming from the same coil. This is for mechanical appearance, and also to assist commutation.

EXPERIENCE ON THE ROAD

W. F. LAMME

MY first experience on the road was as a "trouble" man. To be a successful "trouble" man it is necessary to have some knowledge of the design and characteristics of the apparatus against which complaints are made.

Troubles with apparatus can be divided into two classes—real troubles and troubles imagined; that is, which do not really exist. The latter, the imagined troubles, need not worry the road engineer farther than to think out and present proof that they do not exist in fact. Sometimes a local engineer has imagined difficulties, but before the discovery of his position he has committed himself, and, in order to "make good" he must adhere to his statement that something is wrong. In many cases it is well for the road engineer to act in a diplomatic manner and give the local engineer an opportunity to withdraw gracefully without injuring his standing with his company.

When the trouble is a real one, then it is wise for the engineer to use caution. Most troubles, before they reach the point where an engineer is sent out, have gotten the customer in an unfriendly mood, and when the manufacturer's engineer arrives upon the ground, he finds himself received, in many instances, in an abrupt manner and, in most cases, coldly. The manager may ask you for an opinion before you have looked over the case, and may show displeasure if you cannot give him an immediate answer. He turns you over to his engineer, who, in order to show his loyalty to his company, or because he too is irritated at the state of affairs, gives you an exaggerated and misleading description of the situation. Under the above conditions, and they are numerous, it is best for the road engineer to maintain silence, listen to all that is said but make no judgment in his own mind until he has made investigation for himself.

One of our salesmen sold an alternator. Of the operation of this alternator evidently a very glowing description had been given to the purchaser. The alternator was of the well known compound type, belted to a high-speed engine, with a flywheel governor. The alternator was of standard make and all its characteristics were well known. The load was lighting, therefore nominally non-inductive. The exciter was of ample capacity.

The report on this installation stated that at times great difficulty was experienced in keeping up the voltage; the exciter was much overloaded and two exciter armatures had been damaged; several electrical engineers had experimented upon the case and had secured no satisfactory results, therefore it was not welcome news to be designated for the job. However, the salesman and myself visited the plant and, as usual, met with a chill. The plant was started and everything ran well; the alternator held voltage with a large margin on the rheostats and the exciter was quite cool to the hand. The alternations were about correct, the engine running at, approximately, 250 r.p.m.

Retiring to await developments, we returned in about an hour. Conditions had now changed. The alternator could barely hold voltage, with all the rheostats out and the exciter, laboring under a heavy overload, was quite hot, but I noticed a different hum from that at the start of the machinery. This led me to take speed. I found the engine now running not at 250 but at 217 r.p.m. This explained everything. There was a defect in the engine governor which caused the speed to drop at a certain load and to remain there. After this defect was remedied the engine held speed and the electrical apparatus proved to be in every way satisfactory.

The centrifugal pump driven by an electrical motor, is sometimes a source of annoyance and the motor—"the mysterious thing"—receives the blame. The purchaser will tell you that anyone can calculate the power required to drive a pump, but the electric motor is an incomprehensible piece of apparatus and therefore must be the part at fault. One installation driven by a 10 hp direct connected motor should have required about 6 hp, but the motor ran so hot that frequent shut downs were necessary to permit the motor to cool off: actual tests proved this pump took, approximately, 18 hp and that two-thirds of the required power was expended in churning water. This pump was adapted for a much higher head than that under which it was operating.

Four large alternators in a certain plant would not maintain voltage beyond a load of two-thirds of the capacity of the units. Upon meeting the manager he desired a clear explanation of the difficulty before we had investigated the matter at all. Of course, an intelligent reply to his questions was impossible and he would not accept a statement that we did not know as yet but took the view that we were hiding something.

Proceeding quietly with the work, taking a saturation and regulation curve, according to the methods in vogue at that time, we soon discovered that something was preventing the passage of the magnetic flux through the armature coils. This of course directed attention to the air gap and the pole tips. It was noted that the field bobbins were at a distance back from the tips and that the tips were unusually close together; acting upon the theory that the lines of force must be held in and driven through the armature iron, we dropped the coils close to the armature, and the immediate effect was that we could carry 25 per cent. more load with maintained voltage than before, but still the alternator was not up to the guarantee, so to strengthen the pole tips still more, the back fourth of the field bobbins was cut out and the field current was increased 25 per cent. This accomplished the result desired, and the puzzle was solved, but our troubles were not yet over. Going to the manager we explained that the trouble lay in the field bobbins and we wished to return them, one set at a time, to the factory to be changed, but, he, thinking he had not been treated right, denied the favor at the same time acknowledging that the machine was not satisfactory nor accepted by him. A survey of the situation brought our erecting engineer to the conclusion that this was all a case of bluff and trying to get even with the company; therefore it was resolved to strip one machine that night, which was done, and a complete set of bobbins was out of the plant and in a car before daylight the next morning.

Of course, "blue smoke" rolled about our heads the next day, but after the return of the bobbins from the factory and the machine was put into service again it was so satisfactory to the operators that the manager gracefully acknowledged that he had been beaten.

In a selling office much "charity" and "missionary work" become necessary. For example: A customer reports that his motor is burnt out; an investigation shows, perhaps, that a fuse is blown or the power is off the circuit; another reports his motor is grounded, which means he had a static discharge coming from the belt.

Recently a customer thought something was wrong because the voltage on a compound direct current generator increased when the load came on instead of decreasing. He had always been used to the voltage decreasing with the increase of load and any other condition he reasoned to be wrong.

A party had a two-phase motor operated on a two-phase three-wire system; it became necessary to take this motor down and re-install it in another place, but in connecting up again the common wire was put in one side; of course the motor operated badly, and after much worry and many sleepless nights, the manufacturer was called upon for aid. A few minutes' work put him right and the man showed unmistakeable relief and joy.

KILOWATT HOURS PER CAR MILE

A subscriber on the Pacific coast writes as follows:

"The November issue contains an article by Mr. Graham Bright, 'Tests of Interurban Single-phase Equipment.' On page 655 I find the following sentence:

" 'The kilowatts (kw hours?) per car mile and watt hours per ton mile can be calculated from the average kilowatts which is obtained by integrating the line real kilowatt curves and dividing by the *entire time of run including the stop.*'

"It is true that these quantities can be calculated in the manner indicated, but if so calculated they will not be correct.

"Suppose that the total kilowatt hours of the run, including several stops, be determined by means of an integrating wattmeter. Disregarding instrumental errors, the kilowatt hours so determined will be precisely the same as those shown by integrating the kilowatt-time curves. The watt hours, no matter how determined, divided by the car miles and the ton miles, will give the watt hours per car mile and per ton mile.

"It should be evident to Mr. Bright that car miles and ton miles are functions of distance, not in the least of time: and that if he integrates the curves as he states and divides by the entire time of the run, including the stop, his average kilowatts, with reference to distance, will be low in just the ratio that the time the car is actually in motion is to the total time of the run including the stops.

"It should be evident also that he has only to make his runs short enough and his stops long enough, and calculate the watt hours per car mile and per ton mile according to the method he gives, to make these quantities as low as he pleases."

The original paragraph is obviously in error in omitting the word hours and referring to "kilowatts per car mile" instead of *kilowatt hours per car mile.*

The contention that the length of stop does not affect the power per car mile is quite correct. It is certainly true that "the watt hours, no matter how determined, divided by the car miles and the ton miles, will give the watt hours per car mile and ton mile." The critic determines the watt hours in one way; the original author in another, *i. e.,* they are to "be calculated from the average kilowatts." To make the calculation of kilowatt hours, (which involves time) from the average kilowatts it is clearly necessary to introduce the number of hours. Thus, if during a day of ten hours (during which a car may have stopped many times for various intervals) it is found that the "average kilowatts" are 100, then the kilowatt hours are 1 000 and the kilowatt hours per car mile are found by dividing 1 000 by the total number of miles traveled. It is obvious also that the method specified for finding the average kilowatts is correct. If a single test run is all that is involved the critic's method is simple and satisfactory. If the test includes many runs, Mr. Bright's method should be used.

THE
ELECTRIC JOURNAL

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Some Features of Heavy Electric Traction

Electric locomotives were put into service by the Baltimore & Ohio Railroad Company in the Baltimore tunnel about ten years ago. This first important installation of electricity in steam railway service was popularly supposed to be the forerunner of a large and immediate general adoption of electricity by steam railroads. This innovation, however, was slow to come. In fact, over ten years have elapsed and this initial installation has not yet been duplicated.

An official intimately connected with this work, observing the attractive cost per engine mile, had estimates made for electrical service over a mountain division. The cost of copper, however, ran into such an enormous sum that even a serious discussion of the matter was precluded.

The cost of transmission conductors is a most important factor in the electrification of steam railways. It has prevented the economical adoption of the ordinary direct-current method of operation for heavy service. It is the real underlying factor in the impetus which the single-phase system is giving to heavy traction because it employes higher voltages which greatly reduce the cost of conductors.

Operation under steam railway conditions is quite a different problem from the running of street railways or interurban roads. The most favorable condition for an ordinary electric railway plant is the operation of a large number of small units which thereby distribute the load over the system. In an interurban railway with many sub-stations, six or eight miles apart, it is desirable that some cars be at all times upon each section supplied by a sub-station, so that both sub-stations and the conductors from them may be in continuous service at a fair load. The operation of many small units at frequent intervals has thereby met the commercial requirements for street and interurban railways.

In steam railway operation, however, the economical movement of traffic is in large volume, that is, by long and heavy trains. The important recent advances in steam railway operation have contributed to this end. The capacity of freight cars has been more than doubled; the strength and efficiency of the draft gear has been increased; locomotives have been developed to give greater tractive effort and greater power; with trains of greater length radical improvement in air brake appliance has been secured; rails have been made heavier and bridges have been rebuilt; grades have been reduced and curves have been eliminated; all for the purpose of handling the traffic by longer and heavier trains.

The principal limits to this development are now found in the steam locomotive. The length of its rigid wheel base, the maximum weight on a pair of drivers and the steaming capacity cannot be materially increased.

The electric locomotive operated from a high voltage trolley possesses certain fundamental features which adapt it to overcome these limitations.

The high voltage trolley with sub-stations widely separated so reduces the cost of the transmission system that it is no longer imperative to keep the load upon the system in small distributed units.

The multiple control system, by which a locomotive may be divisible into several separate parts which may be combined into one unit, in so far as the operation by a single motorman is concerned, overcomes the limitations of rigid wheel base and the weight on drivers of the steam locomotive.

Several steam locomotives drawing one train are distinct individual elements under the control of different crews.

The operation of several parts as one individual electric locomotive is as simple as the operation of a subway train in New York, in which six or eight motor cars are simultaneously controlled from a single operating handle.

The horsepower which can be applied to the drawing of a train by locomotives is limited by the boiler capacity, but in the electric system it has no corresponding limit, as all trains receive their power from a large power plant.

In the handling of a heavy freight train up a grade there is no reason why a train should not operate at twenty or thirty instead of ten or fifteen miles per hour, except for the problem of supplying sufficient power. The drawbar pull and the horsepower hours are practically the same for moving a given train a given distance at the higher speed. The time consumed, however, is only half as great.

Instead of supplying one thousand horsepower to each of two trains running ten miles per hour an electric power house can supply two thousand horsepower to a single train at twenty miles per hour with equal facility, thereby reducing the number of train-hours for the handling of a given traffic. The handling of heavier trains or the operation at higher speeds will enable the traffic to be readily handled where there may at present be great congestion, which with steam locomotives could be relieved only by additional tracks.

Incidentally many of the elements of delay in steam operation, such as taking water and coal, failures to steam, drawing fires and the time required for making engines ready for service will be obviated by electric operation.

These are some of the elements which have not been fully appreciated. The adoption of electric operation when applied to any class of service, be it illumination or the operation of street cars, or trains, or machine tools, is wont not only to accomplish more satisfactorily what was done before but to lead to new methods. The introduction of the single-phase system has removed some formidable barriers to the adoption of electricity for railway service, and promises both economy and new methods of facilitating traffic.

F. H. Shepard

The Card Index Idea

The article elsewhere in this issue by Mr. Parsons on an improved system of indexing, emphasizes the great advance which has occurred with respect to classifying and systemizing records in recent years. When text books, reference books and technical journals were few, the man with a fairly good memory could readily recall important articles, and he needed only to be careful about his own note books. Now this is all changed and only men who are librarians like Spofford and Amzi Smith can work with mental records only. Some form of written record is absolutely necessary.

The card-index idea, first used for library catalogues, has proved itself adapted to almost every form of recording data so as to be readily accessible, being now in almost universal use in accounting in the loose-leaf ledgers and other books. Engineers were quick to adopt this most convenient tool, and the younger members of the profession cannot be too strongly urged to begin recording their notes in a systematic way. Most of the technical schools devote some attention to this matter. Obviously it is of the first importance in filing information, that the subject or title should be so shown that it not only covers the data, but that it will be of the form in which the idea will most readily occur to the mind when the subject comes up. Experience demonstrates the importance of this point but it is not always appreciated at first. Hence the value of such articles as that of Mr. Parsons, which discuss the subject of indexing in a scientific way. Besides their chief value, as applied to information in a large way, card-indexes are very helpful even in the smaller work of making individual data readily available.

W. M. McFarland

Power Plant Economics

The paper read by Mr. H. G. Stott before the January meeting of the American Institute of Electrical Engineers on Power Plant Economics is an admirable engineering paper. It deals with the generation of power, and treats, therefore, of the fundamental element in engineering development. It discusses the revolutionary advance in the steam power plant for the generation of electricity which has taken place during the short space of three years in the supplanting of large reciprocating engines by steam turbines. It contains data on the losses in the conversion of coal into electricity, based upon observation for an extended period in one of the largest and most efficient plants in existence. These results are discussed and the probable improvements which can be effected, are shown to result in a possible fuel reduction of about 25 per cent. An interesting presentation is then made of the relative cost of maintenance and operation and the relative investment in plants of several types, employing reciprocating engines, steam turbines, gas engines and certain combinations of these. From this it appears that a plant employing gas engines and steam turbines may produce power at less cost than is involved in present methods. The gas engine is suitable for carrying the constant portion of the load, as it cannot carry heavy overloads, while the steam turbine is adapted for the fluctuative part of the load, as it can carry great overloads. Hence the two work well together for ordinary service.

The gist of the paper is contained in two excellent tables and a summary which are reprinted in this issue of the Journal. The table giving the average losses shows that approximately 10 per cent of the energy in a pound of coal is delivered to the bus bars; and of the remaining 90 per cent, less than 1/3 of one per cent is charged under the head of electrical losses, which indicates that the present perfection of the dynamo has reached a limit beyond which there is little room for improvement.

It is the electric generator and the electric power system which has made possible the modern power plant. The large power plants in Greater New York, for example, could not exist were it not for the electric system to which they supply power. The output of these plants is used primarily for the operation of electric railways, stationary motors and electric lights. This service is used in units ranging from a few watts taken by an electric lamp to motors of several hundred horsepower. Without the electric system it would be impossible to utilize the power produced in generators of thousands of kilowatts output in stations which aggregate hundreds of thousands of kilowatts; in fact, the use of mechanical power would not be employed for many of the present purposes were it not for the electric system. Illumination would be produced by gas and oil and not by steam engines as at present. Street cars would be operated by horses and not by engines; and, many of the operations which are now readily performed by electricity, such as the driving of fans and small machinery, could not be economically performed by any other means.

It is the electric system, therefore, which has made possible the use of mechanical power on a large scale, and which has afforded a ready means for its distribution from large power stations.

It is the dynamo that makes the steam turbine practicable, for there are comparatively few cases in which large quantities of power at high speed can be usefully employed except through the medium of the electric system.

The electric system not only makes possible the utilization of power generated in large quantities for diversified purposes, but is a means of distributing through a common system, the power from many diversified sources. The power from reciprocating engines of various types and speeds, and from steam turbines, and the power from gas engines, may be received into a single system, which may with equal facility receive power from waterwheels many miles distant, and all may operate in common through the agency of electric current for supplying illumination and transportation, heating and mechanical power in varied units for a thousand purposes.

We have a habit of regarding the rapid evolution of electric apparatus as a matter of course. After a century of development, steam power has undergone the most radical transformation in the course of only a few years, and the indications are, that still greater changes may be forthcoming within the next few years. This development is made possible and is accelerated through the new conditions which electricity has supplied; on the other hand, cheaper power insures the larger use of electricity.

Chas. F. Scott

ELECTRIC RAILWAY ENGINEERING

MOTOR CONSTRUCTION*

J. E. WEBSTER

THE improvements in railway motors of the latest design have been made for the purpose of increasing their reliability rather than their electrical efficiency which allows of but little improvement. Careful and extended observations have been made to determine any points of weakness in material or design; these points have been strengthened and corrected. As a result the interval between inspections necessary for safe operation has been greatly increased and the number of cars out of order decreased. Three years ago the intervals between inspections varied from 8 000 to 15 000 miles on the mileage basis, or from one to three months on the time basis. It is not unusual to have the later design of motors in service for a year or more and to have them run 50 000 to 75 000 miles without overhauling. Even this record will probably be greatly exceeded.

Having eliminated four-fifths of the overhauling the motor once required, it is evident that rigidity of construction becomes of the first importance. Accessibility, except as to lubrication and care of brushes, becomes a secondary consideration. The wear of the bearings in the older types of motors determined to a great extent the number of inspections. By the introduction of oil and waste as a means of lubrication, the life of bearings has been so increased that it is no longer the controlling element.

With respect to their size, railway motors may be divided into two groups, those below 80 hp. comprising the type used on city and smaller interurban cars; and those above 80 hp. which are used in heavy interurban, elevated and subway service.

The principal reason for this grouping is the fact that with the smaller motors there is sufficient room between the car wheels and below the car body to allow the design of the motor to be unaffected by space limitations. The armatures are also sufficiently light to be conveniently handled from below the car in a pit. The motors of the largest type are so heavy as to make the use of a hoist or crane necessary in handling, and the long armatures make necessary the use of separate housings or bearing heads extending well inside the commutator and rear armature winding, in order to get sufficient length of bearings.

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*This is the second of a series of articles on Electric Railway Engineering. The first article appeared in the January, 1906, issue.

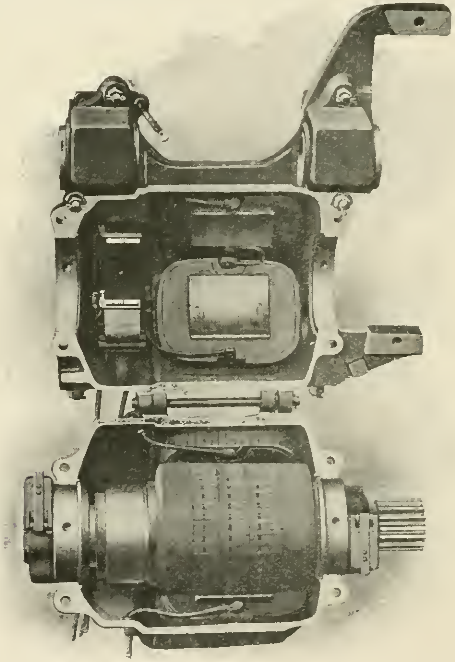

FIG. I—VIEW OF NO. 101B, 40-HORSE POWER, 500-VOLT, RAILWAY MOTOR, WITH LOWER FRAME DOWN

FRAME CONSTRUCTION

Small Type—To remove an armature from below the car it must be possible to drop the lower half of the frame. This requires that:

(a) The field poles project at an angle of 45 degrees from the horizontal.

(b) The axle bearings be supported by the upper half of the frame overhanging the axle and by axle caps which are bolted from below to the upper half frame.

(c) The motor be fastened to the truck on the front or the side opposite the axle, from the upper half of the frame.

(d) The gear case be supported from lugs cast on the upper half of the frame.

Until the adoption of oil saturated waste as a lubricant, some three years ago it was the usual practice to support the armature bearings directly between the halves of the motor frame. Lubrication was provided by means of grease cups cast in the upper frame above the bearings. The bearings at the pinion end were usually split to allow renewals without removing the pinion. This was a great convenience, owing to the short life of the bearings, but had its disadvantage because of the less rigid construction. It is, however, still retained by some manufacturers, even with waste lubrication. The oil reservoir is entirely in the upper half of the frame and communicates with the shaft through an opening in the top of the shell. The lower halves of the armature bearings are supported, in this case, by means of independent caps, bolted to the upper frame of the motor.

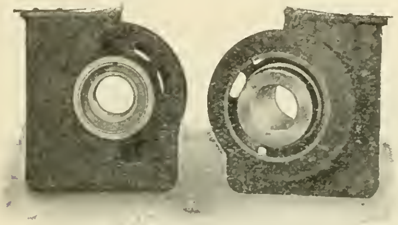

FIG. 2—BEARINGS AND BEARING HOUSINGS

Another new type of small motor construction (See Figs. 1 and 2) retains the separate bearing housings with solid bearing shells. The housing is carried in a cylindrical seat between the two halves of the motor frame. There is a collar on the inner side of the housing fit, which fits against a finished face on the motor frame and takes the end thrust of the armature. The seat of the housing in the frame is bored to the same diameter as the housing, but with thin liners between the two halves of the frame. When the housings are clamped in position, the entire strain of the frame bolts is first thrown on the housings; then, as the bolts are tightened, the outer sides of the motor frame are brought together. In this way the effect of a press fit is obtained and all motion of the housing prevented. The slight spring given the field frame also tends to keep the nuts from loosening on the frame bolts. The bearing housings are also held by tap bolts from both the upper and the lower halves of the frame. The housing thus forms a center piece or keystone around which the whole frame is united as a single piece, all bolts acting together to resist the hard strains of services.

Large Type—The limitations of space available and the weight of parts of motors of from 80 to 200 hp have made changes in design necessary to allow for the longer bearings and for handling the motors from above. Later motors have the pole centers horizontal and vertical, which, with the necessary use of thin flat field coils, gives a square section to the field frame. This frame is either in one piece, known as the box type, with the armature bearing housings bolted in from the ends, or is divided at an angle of 45 degrees from the horizontal, with the bearing housings clamped between the halves of the frame in a manner similar to that of the small type motor already described, except that a tongue on the housing fits in a groove in the seat of the frame. This groove takes the end thrust and keeps the bearings in alignment.

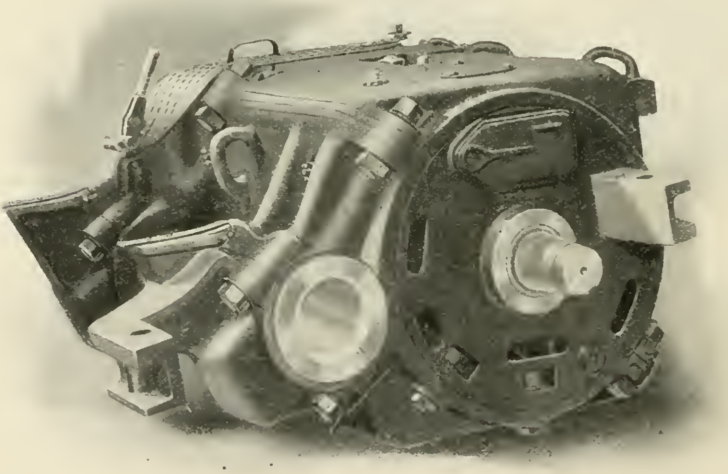

FIG. 3—VIEW OF NO. 121, 90-HORSE POWER, 500-VOLT, RAILWAY MOTOR, PINION END SHOWING MANNER OF SPLITTING BEARINGS, GEAR CASE SUPPORTS, ETC

The advantages of the box type are rigidity of frame and perfect alignment of bearings, as the housings are bolted against finished heads of the frame with a cylindrical shoulder fitting into the frame.

With the split frame motors the armature may be removed while the motor is on the truck, by lifting the front of the motor until the split is horizontal when the upper frame can be raised.

To take out the armature of a box type motor, the motor must be removed from the truck and the armature taken from the end of the motor. Either type of motor can be removed from the truck by removing the axle caps.

It is very desirable to have the motor frame extend well over the axle with the caps bolted on from below. This relieves the cap bolts of practically all strains and prevents motors from dropping. See Fig. 3.

GEAR CASE SUPPORTS

The gear case must ride with the motor, therefore, it must be supported from the end of the motor frame. The following two methods are now in general use: The three-point suspension which has two lugs at the bottom of the upper half bolted to pads on the motor frame and a tie from the top of the case to the motor frames. In this type the case is carried from the side and thus the stresses are concentrated in the pads and tapped lugs. The second method is shown by Figs. 4 and 5, where the case is supported at the ends upon two horns, which are cast on the motor frame. This plan divides the stresses almost equally through the whole case and prevents breaking, and by its simplicity makes possible the use of light sheet steel cases.

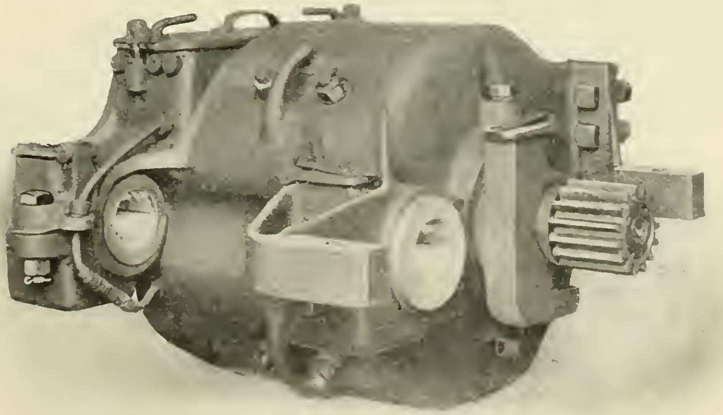

FIG. 4—VIEW OF NO. 101B, 40-HORSE POWER, 500-VOLT, RAILWAY MOTOR, PINION END, SHOWING GEAR CASE SUPPORTS

FIELD COIL SUPPORTS

Field coils should be so held in position as to prevent any chafing against the poles or frame. This is done either by supporting the coil between the projecting field pole tips and a heavy flat spring which rests against the motor frame or by bolting the coils to the frame by means of special hangers.

ARMATURE CONSTRUCTION

All railway motor armatures are subjected to enormous strains, owing to reversals, broken gears, or pinions and similar causes. The armature construction must be very rigid to meet these strains, with all parts strong and thoroughly locked together. There are two types of construction in general use. The older method is to assemble the commutator, the armature heads and the laminations separately on the shaft, and to press them in position from the commutator end and hold them in place by a heavy nut in front of the commutator. A modification

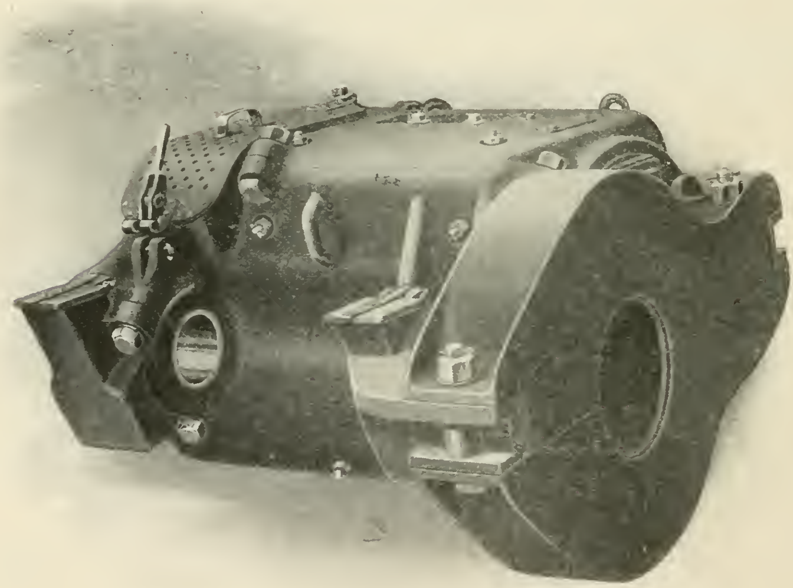

FIG. 5—VIEW OF NO. 121, 90-HORSE POWER, 500-VOLT, RAILWAY MOTOR, WITH GEAR CASE IN POSITION

[illegible]

of this scheme is to force the commutator on the front armature head. In case it is necessary to remove a bent or broken shaft on the latter type of armature, long tap bolts are passed from the pinion end through the ventilating ducts in the laminations and screwed into the commutator end head holding all parts in place. On the larger sizes of motors it is necessary in order to obtain sufficient room for bearings, to carry the pinion end head several inches into the punchings.

A more recent construction is to provide a one-piece spider or quill, upon which all parts of the armature are built. The shaft is pressed and keyed in this spider. This construction makes it possible to remove the shaft without, in any way, affecting the different parts that carry the winding. As bent or broken shafts usually occur after the fibrous portion of the insulation is brittle, its life is apt to be materially decreased by strains.

Great care must be used in getting the proper fits between the laminations and the shaft or spider as well as the pressed fits between the commutator, spider and shaft. A chattering between any of these parts produces very rapid wear and is difficult to stop.

COMMUTATORS

As the rating of any motor depends on its temperature rise, or the relation of its losses to its capacity to radiate heat, and on its commutating capacity, the design of the commutator, both as to dimensions and numbers of bars must be liberal. Large diameter is important in that it allows a wider brush to span the allowable number of bars and thus decreases the current density in the brush. The design of the commutator should call for sufficient strength in the steel V-rings and in the copper bars, at least one-sixteenth inch of firm built-up mica insulation on the V-rings, a close fit on both angles of the V and a strong tightening and locking device. The latter is usually a ring nut on the smaller sizes or a number of tap bolts between the front and rear V-rings on the larger sizes.

BRUSH HOLDERS

The brush holder design and construction is a very important factor in determining the interval between inspections. A successful brush holder must have: insulation with large creep-age distances to prevent flashing due to accumulations of dust, rigid support and pressure fingers that are light and that give approximately a uniform tension over the working range of the brush.

The insulation requirements are best met by the use of mica tubes moulded on rods which are either pressed in iron sockets or clamped between iron blocks. The part of the surface of the mica which is clamped is protected by sheet metal tubes and the part between the holding blocks and the brush holder proper by porcelain rings. This leaves porcelain as the only exposed insulation surface.

VENTILATION

As has been stated, the commutation and the radiating capacity of a motor determine its rating. This radiating capacity can be greatly increased if a current of air can be kept passing through the armature and around the field coils where the copper and iron losses occur. This current may be cool air drawn from openings left in the motor frame, or it may simply be a circulation of the internal air in a closed motor carrying the heat from the working parts to the inside of the frame and thus increasing the outside radiation. This circulation is induced by the rotation of the armature forcing air through openings leading into the center of the armature at the pinion end and out through ducts left between the punchings. The best practice is to keep the ventilation through the metal part of the armature and away from the insulation, as dust is ever ready to lodge in any crevice or break in the wrappings on the conductors and cause insulation break-downs. The decision as to whether outside air be admitted to the motor frame is best decided by the ability of the insulation to withstand dust and the amount to be expected from the brakes or the track. Openings are provided in the pinion end of most modern motors either directly, for the entrance of air, or for the air and the drip of the oil from the bearings. The exhaust is either through similar openings in the commutator end or through perforations in the commutator cover. With properly sealed windings and the modern brush-holder insulation, neither of which is affected by dust, the increased life of the insulation due to the lower temperatures obtained by ventilation will justify its use. On large locomotive motors, air blasts are obtained by means of blowers in the cab.

INSULATION

Cotton, fibrous material, asbestos, mica, paints and gums or varnishes comprise the materials used in railway motor insulation. With the exception of asbestos and mica all become more or less brittle and charred when subjected to continuous temperatures of 100 degrees C. For this reason 65 to 90 degrees C. has been set by practical experience as the highest temperature at which the motor windings can be safely operated in service. A load which gives a temperature rise of 75 degrees C. above the air by thermometer on shop test will give, when in service, a temperature within these limits, owing to the better ventilation under a moving car. The temperature rating of a railway motor is arbitrarily based on the load it will carry for one hour with a temperature rise of 75 degrees C., as measured by a thermometer.

Armature Insulation—On wire wound armatures, which are those requiring more than one turn per coil to obtain the necessary counter-electromotive force to give the speed desired, cotton covered wire has been and still is used. It is not possible as yet to obtain on the market a wire with a strong or tough asbestos or fireproof insulation of a sufficiently small section at a cost which will warrant its general use. With the use of cotton covered wire, there is no advantage in the use of a mica wrapper except where space is of great importance. The outside insulation of wire wound coils therefore usually consists of a cell or wrapper of treated paper or cloth over the portion of the coil in the slot with one or more overlapping layers of tape over the whole coil. The tape can be applied after treatment with an insulation compound or the unfilled cotton fibre can be applied dry and filled when in place by repeated dippings in the compounds, an oven drying following each dipping. The latter method allows the free fibre of the tape to adjust itself to the form of the coil and gives a perfect seal which prevents the entrance of dust between the layers of tape. Where more than one coil per slot is used, spacing strips can be used between the wires of adjacent coils. The dipping which the finished coil receives also fills the cotton wrapping on the wire.

The large type of armatures are wound with copper strap with but a single turn per coil. This allows of a heat resisting insulation applied either as a mica tape of a good many layers or by a judicious use of mica wrappers both built up on thin paper. Even with this construction a cotton outside taping must be used, and temperatures must not be attained which will injure this as the mica will then loosen, due to the constant vibration.

Field Coil Insulation—The space limitations and the less severe service and winding strains allow of the use of more bulky asbestos and cotton covered wire on the smaller field coils in place of the cotton covered wire used on armature coils. Each layer of wire is treated with a filling and insulating compound while winding, which helps to bind the wires together, and, as this compound is not affected by the maximum temperatures which the coil will attain even when the cotton in the center of the coil is charred, it holds the asbestos in place and prevents the turns coming together.

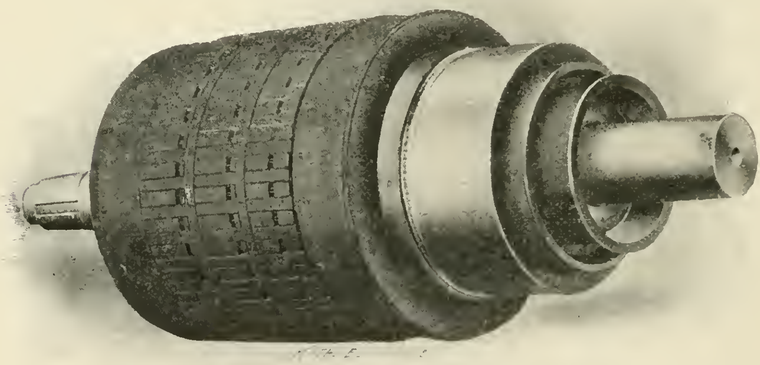

FIG. 6—VIEW OF NO. 101B ARMATURE, SHOWING METHOD OF BANDING

In a great number of motors of even the latest design, the above method is used except that no compound is used when winding, but the completed coil, after having part of the outside taping applied, is thoroughly impregnated with a gum by the vacuum process which insures perfect drying and filling.

On the later types of Westinghouse motors the field coils are wound in sections of copper ribbon, one, two, or four sections comprising a complete coil. An asbestos ribbon is wound in between the straps. The separate sections of a single coil are assembled with an asbestos and mica strip between and the whole coil is impregnated as above. With this form of coil the whole interior is fireproof. In case of injury to a strap wound coil, only the injured turns need be rewound as there is no weakening of the insulation on the remainder of the turns as in case of the asbestos and cotton wire. The wire wound coil when not opened, will stand quite severe internal overheating, but if the arrangement of wires is interfered with, as would be necessary in making repairs, the insulation will crumble away, making it necessary to reinsulate and rewind the whole coil.

ARMATURE WINDING AND BANDING

All wire wound railway armatures have two or more turns per coil and usually three coils per slot. The coils which lie in the same slots are assembled and insulated together. This makes it necessary to finish the winding by reaching the lower portions of the coils which lie in as many slots as comprise the throw or spread of a coil in under the upper portions of the coils which lie in these slots. This is done without injury to the more flexible wire wound coils, but with the less flexible strap wound coils, which usually consist of from three to five single coils per slot, this would be difficult. For this reason and also to facilitate repairs, the strap coils are almost universally divided at the rear of the armature, the joint being made by a clip. As a great part of the armature coil troubles occur at the surface, repairs can be made by simply removing the injured upper halves.

In order to distribute the strain of the band over a considerable portion of the coil in the slot and to protect the coil from injury at the surface, a fibre wedge or strip is placed above the coil in the slot. This strip should extend, even when the coil is firmly driven in the slot, slightly above the surface of the banding groove, so that there will be no chance of the coils being loose in the slots. Looseness will cause chafing and eventually insulation breakdown.

In banding, a very strong well tinned steel wire, of sizes varying from 14 to 17 B. & S. guage, should be used. A fibrous strip at least .02 inch thick should be placed immediately below the bands on the end windings. Tinned sheet steel clips should be placed not more than 3 inches apart under the bands, and the ends which are doubled over the bands should be well filled with solder after the complete band is sweated full of solder. The arrangement of bands on standard armatures is well shown by Figs. 6 and 7.

BEARINGS AND SHAFTS

The present standard sizes of shafts and bearings are the result of actual service experience rather than theoretical calculations, or rather the factors have been greatly increased after experience with the heavy strains due to reversing, flashing and brokn gears or pinions. Several years of service with the present sizes, which are given in all motor trade circulars, indicate that no further increase will be necessary.

The best grades of babbitt have proven themselves the most desirable metal for armature bearing linings. On all of the larger motors and some of the smaller ones a lining from three-thirty seconds to one-sixteenth of an inch thick is soldered to the inside of a finished bronze shell. In case the babbitt lining should become overheated and melt, the armature would still be carried above the pole pieces by the brass shell. On some of the smaller motors, owing to the remarkable efficiency of the lubrication used and the difficulties involved in resoldering a bearing, especially in the smaller shops, a cast iron shell with numerous cored anchor pockets is used with a three-sixteenth inch lining of babbitt. This method gives a longer life to the bearing. The seats of the motor bearings are commonly bored with centers one-thirty-second of an inch above the pole centers so as to give greater wear to the bearings.

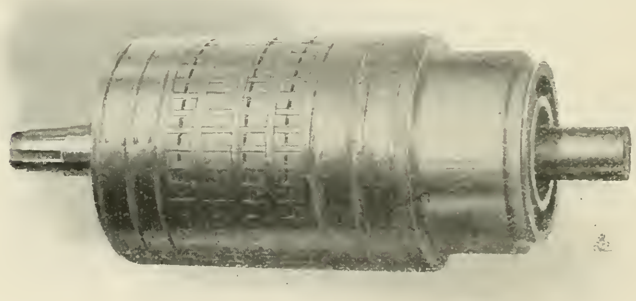

FIG. 7—VIEW OF NO. 121 ARMATURE, SHOWING METHOD OF BANDING

The axle bearings are usually the same as the motor bearings on any motor except on the larger sizes. Unbabbitted bronze shells are sometimes used and malleable iron is substituted for the cast iron shells.

LUBRICATION

In laying out a bearing for oil-saturated waste lubrication, the two most important features to be considered are: first to so shape the waste reservoir that the waste cannot fall away from the journal owing to gravity and to the constant vibration of the motor; and, second, to provide for carrying and measuring the oil supply below the lowest point of contact of the waste with the shaft. The separate armature bearing housing provides ample space for complying with these requirements. With separate housings for the armature bearings, a deep waste reservoir may be used, extending several inches above the shaft, with the waste in contact with the shaft at the low pressure side. This arrangement keeps the waste from falling away with consequent loss of lubrication. With the proper shape and size of waste reservoirs, a very small quantity of oil is needed to give good lubrication. On one road where this type of motor is being used, each bearing is given two or three tablespoons full of oil every fifth night. The wear on these bearings after a year's service has been very slight. These results are possible only where the depth of pocket is sufficient to allow the full oil level to be from one and one-fourth inches to

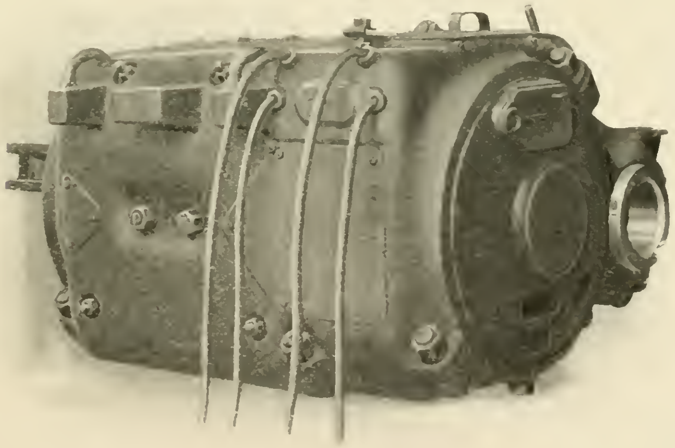

FIG. 8—VIEW OF NO. 121, 90-HORSE POWER, 500-VOLT, RAILWAY MOTOR, SHOWING METHOD OF BRINGING OUT LEADS, LOCATION OF COVERS, ETC

two and one-half inches below the opening which communicates with the shaft. With a higher oil level the feed is greater than the bearing demands. This of course prevents good oil economy.

In order to obtain the most economical use of oil, the oil level in the waste should be just enough below the lowest point of contact of the waste with the shaft to give the feed required. This level can be determined by careful observation of any motor in service, after which it can easily be maintained by gauging the wells before oiling.

The oil and waste to be used should be of similar grades to those used by the steam roads for car journal lubrication and should be prepared in the same manner. Before packing the waste should be immersed in oil for 48 hours, then the threads pulled apart, forming soft springy balls.

The openings in the bearing shells are usually from 55 per cent. to 70 per cent. of the total length of the shell and from 70 degrees to 90 degrees wide.

MOTOR SUSPENSION

On the smaller sizes of motors, the latest practice is to suspend the motor at the front by means of a heavy bar which is bolted to the motor and supported by springs at each end on the truck frame.

On the larger type there is a heavy lug cast on the motor which rests on the truck transom and is held in place by means of a U-shaped clamp.

DETAILS

There are a great many details such as the manner of bringing out the leads, the shape, location and latching of inspecting covers, that must be arranged to suit the conditions of the service on which the motors are to be used.

NOTE—The denominator of formula (2) given in the January issue at the end of the article on Electric Railway Engineering should read 375 instead of 0.375 as printed.

INDUCTION IN TRANSMISSION CIRCUITS

AN ELEMENTARY CONSIDERATION OF THE PHYSICAL BASIS UNDERLYING SELF INDUCTION AND MUTUAL INDUCTION*

CHAS. F. SCOTT

A definite understanding of the physical relations between current, the field produced by the current and the electromotive force induced by the field in parallel circuits is essential to clear ideas regarding self induction and mutual induction.

(1.) Current flowing in a straight wire induces a magnetic field; the lines of force are circular and surround the wire. The density of the field is greatest at the surface of the wire and at more distant points it varies inversely as the distance from the center of the wire.

The field surrounding a wire carrying current is represented in Fig. 1. The circles are close together near the wire where the density of field is greatest.

A curve showing the relative density of the magnetic field surrounding the wire at different distances is given in Fig. 2. In this curve the density at the surface of the wire is 100; at a distance from the center equal to twice the radius, the density is one-half as great, or 50; at four times the radius, it is 25; at five times, 20; at ten times, 10; and so on.

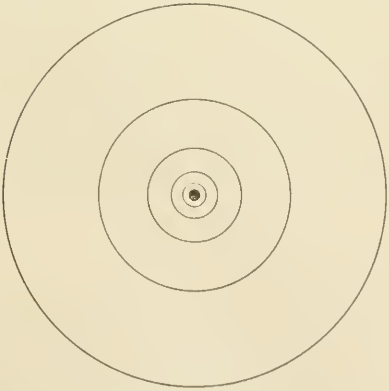

FIG. 1—MAGNETIC FIELD SURROUNDING A CURRENT-CARRYING WIRE

(2.) The field density at the surface of wires of different diameters carrying the same current is inversely proportional to their radii; e. g., if the density at the surface of a given wire is 5, that at the surface of a wire of half the radius is 10.

The field density produced at equal distances from the centers of wires of different diameters carrying equal currents is independent of their diameter, consideration being given to the field external to the wires themselves. Thus, if two wires, one of which has one-fourth inch and the other one-tenth inch radius, carry equal currents, the strength of the field at one-half inch or any greater distance from the center of one of the wires is equal to that at the same distance from the center of the other wire. Diagrams showing this relation are given in Fig. 3.

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*A lecture before The Electric Club, and one of several articles to appear in the JOURNAL dealing with the characteristics of transmission circuits. The first article in the series was published in the December, 1905, issue.

(3.) The total field lying between the surface of the current-carrying wire and a distant parallel line is proportional to the area of the curve shown in Fig. 2, measured from the surface of the wire to the line. If the radius of the wire be taken as unity then the total field between the surface of the wire and a parallel line which is distant 2 units from its center is proportional to the area between the curve and the base line, measured between vertical lines at the surface of the wire and at distance 2. This area contains approximately 69 small squares. If the parallel line be at a distance of 3 from the center of the wire, the area is seen to be 110 squares.

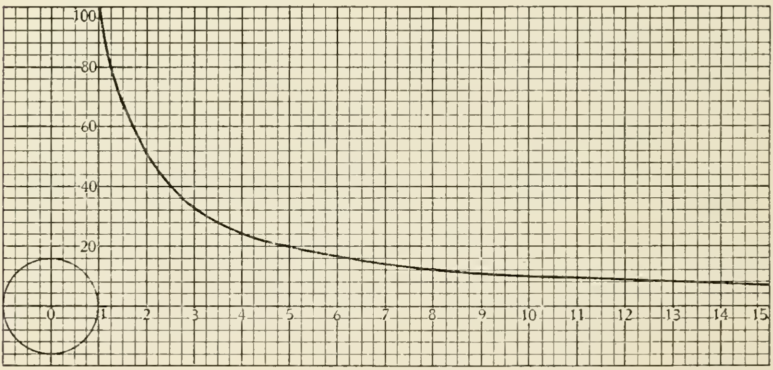


FIG 2—CURVE OF DENSITY OF MAGNETIC FIELD PRODUCED BY CURRENT IN A STRAIGHT WIRE. ON HORIZONTAL SCALE THE RADIUS OF WIRE EQUALS ONE

Instead of measuring the areas in this curve it is convenient to construct a second curve which will show at once the value of the area in the curve Fig. 2, included between the surface of the wire and a line at any distance from it. Such a curve is given in Fig. 4. In this curve the value of the ordinate at 2 on the base line is 69, which is the area of the curve in Fig. 2 as above described. The ordinate at 3 is 110. The value of the ordinate at any point on the base in Fig. 4 is equal to the area of the curve to the same point in Fig. 2. It may be noted that the curve in Fig. 2 is an hyperbola, and that in Fig. 4 is the logarithmic curve. The curve in Fig. 5 is the same as that in Fig. 4, but the scale is different. These curves possess some interesting properties, which will be discussed later.

(4.) If the field be produced by an alternating current, an e. m. f. will be induced in any secondary circuit located in the field in such a position that the lines of force pass through it. Thus, if two wires lying parallel with the wire carrying current and at different distances from it, are connected together at their respective ends they will constitute a secondary circuit in which an e. m. f. will be produced which is proportional to the total field passing through it. The total field is dependent upon the position of the secondary circuit with respect to the current-carrying wire, and is proportional to the current strength, the frequency and the length of the wires.

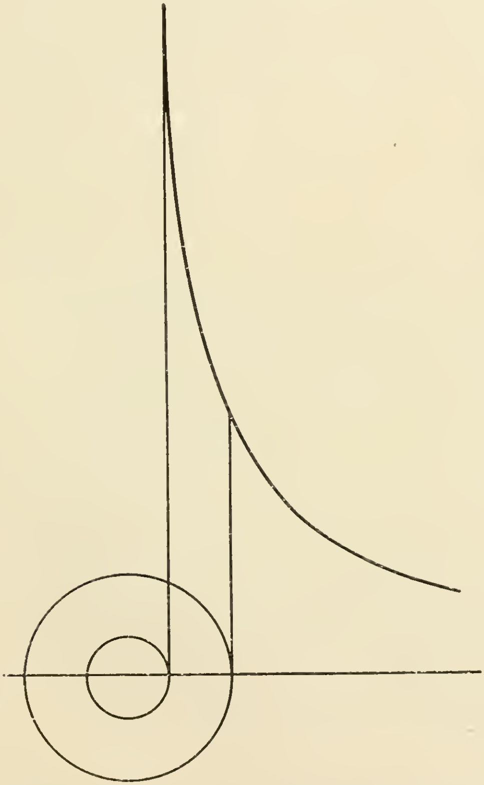


FIG. 3—CURVE OF DENSITY OF MAGNETIC FIELDS PRODUCED BY EQUAL CURRENTS IN SMALL WIRE AND IN LARGE WIRE

The density is the same at equal distances from the center provided the distance is greater than the radius of the larger wire.

(5.) If one of the secondary wires be placed at the surface of the conductor carrying current and the other at a distance from it, the total induction in the secondary circuit corresponding to different positions of its return wire may be determined from the area of the curve in Fig. 2 measured out to the return wire, or from the ordinate in the curve in Fig. 4 at the position of the return wire.

It will be found that if the secondary return wire be moved so that the distance is doubled there is a certain definite increase in the e. m. f. which is independent of the absolute values of the distance. Thus, a movement of the wire from a distance 3 from the center to a distance 6 produces the same increase as a movement from 6 to 12, or from 10 to 20, or from 15 to 30. Moreover, the amount of this increase may be found by dividing the greater distance by the less (which gives 2 in this case) and finding from the curve the value when the wire is placed at this distance (in the present case at a distance 2 times the radius from the center). An examination of the curve shows that the value at 2 is 69, and also that the difference between the values at 6 and 3, or at 80 and at 40, etc., is 69. This ordinate at 6 is 179 and that at 3 is 110 and the difference is 69; the ordinate at 80 is 437 and that at 40 is 368, and the difference is 69. If the wire be moved successively by a distance which is in a geometrical ratio (e. g., if each movement doubles or trebles or quadruples the distance) each movement produces an equal increment in the e. m. f.

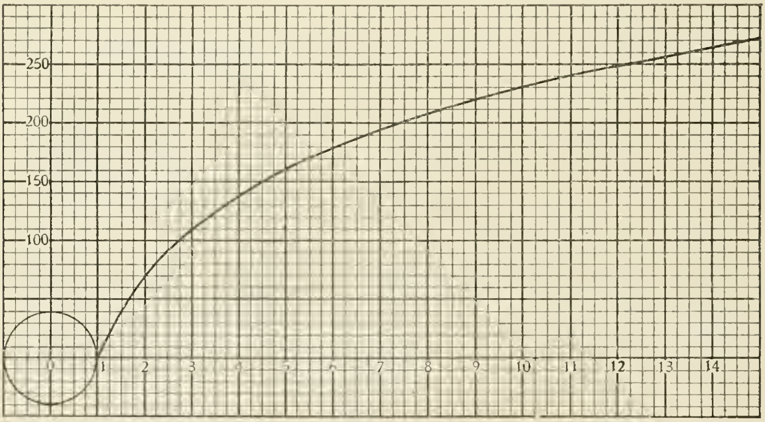


FIG. 4—CURVE OF TOTAL FIELD PRODUCED BY CURRENT IN A WIRE, MEASURED FROM SURFACE OF WIRE TO DIFFERENT DISTANCES FROM ITS CENTER

If, in a given case, a change in position of the return wire from a distance of 1 inch to 10 inches causes an increase of e. m. f. of 1 volt, so likewise will a change from 1 foot to 10 feet, or 10 feet to 100 feet cause a like increase, and furthermore, 1 volt is the e. m. f. induced when the return wire is at a distance 10 from the center of the current-carrying wire (i. e., a distance of 10 times the radius of that wire).

(6.) In the foregoing cases, one side of the secondary circuit is assumed to be at the surface of the current-carrying wire. If it be at a distance from the wire the induction through the secondary circuit and consequently the electromotive force in it may be found from the same curves. The induction in the secondary circuit is proportional to the area of the curve measured between the two sides of the secondary circuit. Thus if one of the secondary wires be at a distance 5 and the other at a distance 10 from the center of the current-carrying wire, the area in Fig. 2 is to be measured between these two points. It is likewise obtainable from Fig. 4, by taking the difference between the ordinates at 10 and at 5. This difference has the same value for any two distances, one of which is double the the other. Likewise, if the distance of one secondary wire be *n* times the distance of the other from the current-carrying wire, the induction in the secondary circuit is the same, whatever be the absolute value of *n*. For example, the induction (and consequently the e. m. f. in the secondary circuit) is the same, provided one of its sides is four times as far from the current-carrying wire as is the other side, independent of the absolute distances, which may be 1 inch and 4 inches, or 15 inches and 60 inches, or 2 feet and 8 feet.

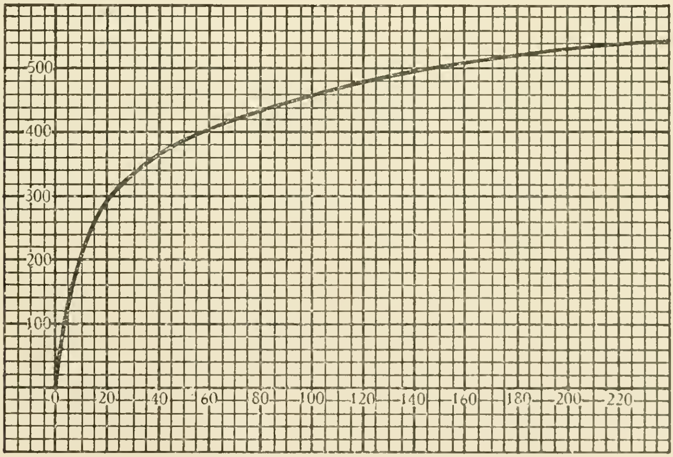


FIG. 5—CURVE SHOWN IN FIG 4 EXTENDED TO INCLUDE GREATER DISTANCES

(7.) The foregoing law holds whether the three wires are in the same or different planes. This follows from the fact that the field as shown in Fig. 1 is circular. The induction lying between the current-carrying wire and a second wire a foot from it is obviously unaffected by the angular position of the second wire which lies on the circle of one foot radius. If the current-carrying wire and one of the secondary wires lie in a horizontal plane, the other secondary wire whatever its position may be imagined to be revolved in a circle about the current-carrying wire into the horizontal plane without changing its effective position in the field. Consequently as the ratio of the distances of the two secondary wires from the current-carrying wire is the essential thing it is immaterial whether or not the wires are in the same plane.

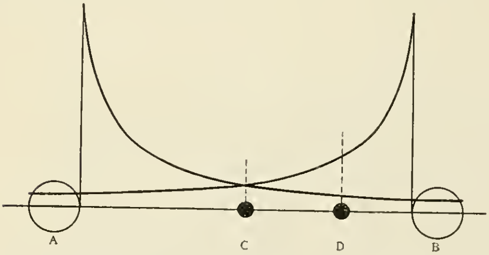


FIG. 6—CURVES SHOWING DENSITY OF FIELD WITHIN SECONDARY CIRCUIT *C-D*, PRODUCED BY CURRENT IN CIRCUIT *A-B*

(8.) So far, but one current-carrying wire has been considered. The return wire carrying current also produces in the secondary circuit an induction and an e. m. f. which can be found from the curves in the manner above described. The resultant e. m. f. is either the sum or the difference between those produced by the two current-carrying wires. If the secondary wires lie between the current-carrying wires, as in Fig. 6, then the resultant is found by addition, as the field on the left side of a current flowing in one direction is in the same direction as that produced on the right side of an opposite current.

In Fig. 6 the density of the field produced by the current-carrying wires is plotted in curves similar to that in Fig. 2. The total induction lying between the two secondary wires is found by adding together the areas of the portions of the two curves which lie between the secondary wires. In accordance with the method which has already been described, these areas may be obtained by using the curve in Fig. 4.

If the two current-carrying wires lie close together as is shown in Fig. 7 then the resultant field produced between the two secondary wires is the *difference* between the fields produced by the current-carrying wires independently for the reason that the secondary wires lie to the right of both of the current-carrying wires and as the currents in them are opposite in direction, the fields passing through the secondary circuit are likewise opposite in direction. Each part of the induction may be determined either by the use of the curve in Fig. 2 or that in Fig. 4.

In Fig. 8, *A* and *B* are the wires of a circuit carrying current. The induction in a second circuit, *C* and *D*, produced by current in *A* may be found from the curve in Fig. 2 by measuring the area between two points on the base located at distances proportional to the distances of *C* and *D* from the center of the current-carrying wire. If the ratio of the distance *a* to *b* is as 7 to 15, then the area may be measured between 7 and 15. Or, the curve in Fig. 4 may be used, as the effect in the secondary circuit is represented by the difference between the ordinates at 7 and 15 (or any other two points whose distances from the current-carrying wire are in the same ratio, such as 14 and 30, or $3\frac{1}{2}$ and $7\frac{1}{2}$). Likewise the effect in the secondary circuit due to the other return wire, may be found by means of the distances *c* and *d* of the secondary wires from it. The resultant induction in the circuit is the sum or difference of the effects produced by the individual primary wires. Inspection of the arrangement of the wires in Fig. 8 (as well as in Figs. 6 and 7) shows that if the secondary wire which is nearer to primary wire *A* is also nearer to primary wire *B* than is the other secondary wire, the resultant in the secondary circuit is the difference between the individual effects; and otherwise it is the sum.

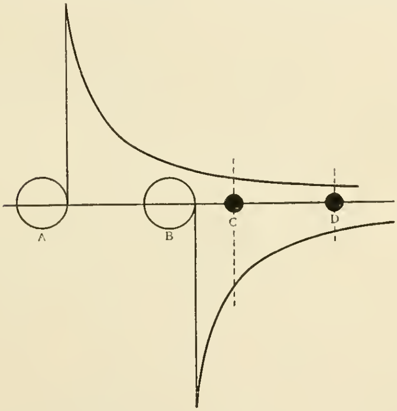
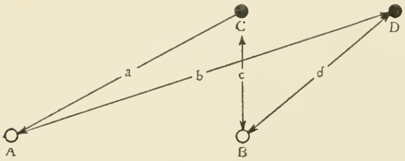


FIG. 7—CURVES SHOWING DENSITY OF FIELD WITHIN SECONDARY CIRCUIT *C-D*, PRODUCED BY CURRENT IN CIRCUIT *A-B*

(9.) If the two secondary wires shown in Fig. 6 be moved apart the induction between them will increase. If they be moved to the surfaces of the two current-carrying wires then they will include the total induction between these two wires. If the current-carrying wires be imagined to be hollow and the secondary wires be placed at their centers then the secondary circuit will include the total induction lying between the current-carrying wires and also between the centers and their surfaces. The strength of the latter field may be considered as proportional to the distance from the center. The conditions are therefore represented by a triangle as shown in Fig. 9.

The secondary circuit located at the centers of the current-carrying wires occupies the same position as the current-carrying wires themselves. Consequently an equal e. m. f. is produced in the original or primary circuit, as is produced in the secondary circuit which occupies the same position. Consequently the e. m. f. which the circuit induces in itself, which is called the e. m. f. of self-induction, is a particular case of the induction produced by one circuit upon another, which is termed mutual induction.

The self-induction of the circuit may be determined by means of the curve in Fig. 2 or the curve in Fig. 4 by using these curves to determine the total induction lying between the surface of each wire and the center of the other wire. To this must be added the area of the triangles representing the induction between the center and the surface of the wires.



FI. 8 — DIAGRAM SHOWING MEASUREMENTS NECESSARY TO CALCULATE E. M. F. INDUCED IN SECONDARY CIRCUIT *C-D* BY CURRENT IN *A-B*

As the induction density at the surface of a wire is inversely proportional to its diameter, it follows that if the diameter be, say, twice as great, the height of the triangle representing the field in the wire is half as great and the base of the triangle is doubled. The area is therefore unchanged Consequently the value of the total field within a wire is independent of its diameter.

(10.) If the size of the wire be increased and the distance between the two sides of the circuit be held constant, then the induction lying between the two wires is reduced because there is less distance between the surfaces of the wires. If in Fig. 2 the size of wire be doubled then the area of the curve between the points 1 and 2 on the base line disappears and the field external to the larger wire is represented by the curve beyond the point 2. The fields due to equal currents in conductors of different sizes are shown in Fig. 9.

If, however, the two larger wires be separated by twice the distance so that the ratio between distance and diameter is constant then the induction between the wires is the same, because the area added by the separation of the wires just compensates for the reduction in area near their surfaces. Thus, if in Fig. 2 the second wire be initially at a distance 5 from the first wire and the size of wire then be doubled and the distance doubled, the area between 1 and 2, which is equal to 69, will disappear and there will be added a new area between points 5 and 10 which will likewise be found to be 69.

For equal currents therefore the e. m. f. of self-induction is constant for wires of different sizes provided the distance between the wires be proportional to the diameter. It is obvious from an inspection of the curves and figures that a change in the diameter of the current-carrying wire does not affect the e. m. f. induced in other circuits, also that the e. m. f. induced in a circuit by its own current does depend upon the diameter of the wires if the distance between the wires is constant. If the wires are close together this difference may be considerable. If the wires are widely separated then a change in diameter produces a relatively small effect in the e. m. f.

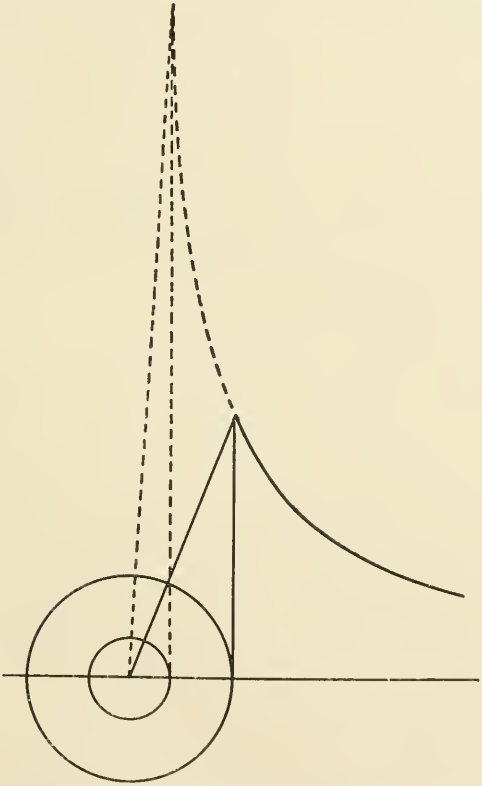


FIG. 9—CURVE OF DENSITY OF MAGNETIC FIELDS WITHIN AND WITHOUT A SMALL WIRE AND A LARGE WIRE

(11.) The foregoing facts regarding the e. m. f. induced by a current in its own circuit and in adjacent parallel circuits have been deduced from the simple fundamental law that a field outside of a conductor is inversely proportional in strength to its distance from the center of the conductor, and that the field within a wire is directly proportional to the distance from the center. Many of the conclusions which have been drawn may be more simply expressed by formulae or the results may be expressed in the form of tables. It is useful, however, to have a clear understanding of the laws upon which the formulae and tables are based. A study of the relative results under various conditions as to positions of circuits can frequently be better considered by an application of the curves than by formulae.

(12.) The foregoing discussion considers relative values only. The induced electromotive forces are proportional to the primary current, to the frequency and to the length of the circuit.

The curves in Figs. 4 and 5 have horizontal scales which are plotted in terms of the radius of the wire. The scale may be used as an inch scale for the determination of the electromotive force induced in a secondary circuit (provided the secondary wires are more than one inch from the center of the primary wire, which may be of any radius not exceeding one inch). If the current is 100 amperes, the frequency 60 cycles and the distance 1 000 feet, then 435 or the vertical scale corresponds to approximately one volt, Under similar conditions except that the frequency is 25 cycles, 1 050 on the vertical scale corresponds to 1 volt.

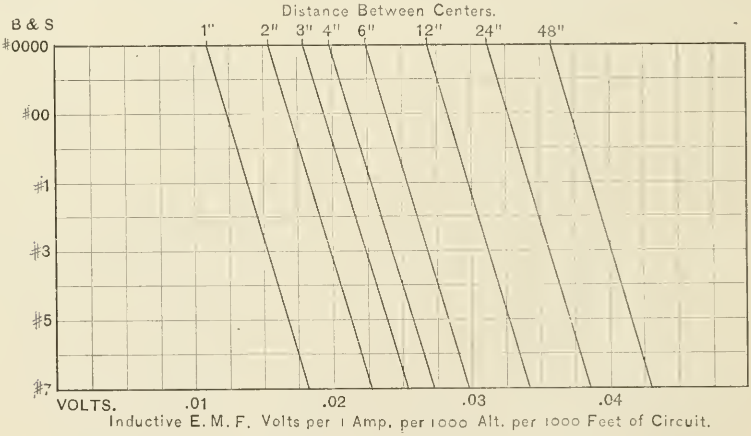


FIG. 10—E. M. F. INDUCED IN A CIRCUIT BY CURRENT FLOWING IN THAT CIRCUIT

The volts induced in a circuit by its own current are given in Fig. 10 which is reproduced from page 720 of the JOURNAL for December, 1905.

(13.) A table of reactances by Mr. Henry W. Fisher* given on the next page contains data for determining the volts induced in a circuit by its own current. The reactance in ohms is equal numerically to the volts induced by the flow of one ampere. An examination of this table shows a number of the relations which have been discussed in the preceding paragraphs. The increase caused by doubling the distance is constant and is 0.032, independent of the size of wire. Comparing values for ½ and 1 inch, 1 and 2, 2 and 4, 3 and 6, 4 and 8, 6 and 12, etc., it is seen that the difference is constant. Hence the table may be extended; the value for 120 inches is equal to that for sixty inches plus 0.032. The corresponding constant for twelve-fold increase in difference is found by subtracting the values in the table for 1, 2, 3, 4, and 5 inches from those for 12, 24, 36, 48, and 60 inches respectively. The difference is 0.114. Therefore the values in the table for inches may be changed to those for the corresponding numbers of feet by adding 0.114.

The effect of diameter of conductor is readily seen by comparing values in the vertical columns. The reactance changes much more when the conductors are close together, than when they are far apart. At 60 inches the change is only 35 per cent. when the diameter is increased 16 times. The volts induced by the same current are therefore approximately the same, but heavier currents are usually carried in the heavier conductors.

(14.) It is useful to compare the reactance in the table with the resistance in order to appreciate its relative practical importance. If it is known whether the volts required for overcoming reactance are more or less than those necessary for overcoming resistance a fair idea may readily be formed of the importance of the reactance in any given case. An examination of the table shows that the reactance at 60 cycles is less than the resistance for No. 2 B. & S. gauge and smaller sizes, for distances between wires not exceeding 60 inches. For No. 000 gauge the reactance at 3 inches is approximately equal to the resistance, and at 36 inches is double the resistance.

At 25 cycles the reactance is proportionately less than the values for 60 cycles given in the table. The reactance at 25 cycles is less than half the resistance, for No. 1 gauge and smaller sizes, for distances not exceeding 60 inches. The reactance is less than the resistance, for No. 0000 gauge and smaller sizes, for distance of 36 inches and less.

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* Trans. A. I. E. E., June, 1905.

TABLE OF REACTANCES

BY H. W. FISHER

Size of Conductor in B. & S. Guage	Diameter in Inches	Resistance in ohms per 2000 ft. of Wire at 68° fahr.	Reactance in ohms per 2000 ft. of wire at a frequency of 60 cycles per second Distances between centers of conductors in inches													
			½	1	2	3	4	5	6	8	12	18	24	36	48	60
Solid 10	0.1018	1.994	0.116	0.148	0.1803	0.199	0.212	0.223	0.231	0.244	0.2626	0.281	0.294	0.313	0.326	0.337
8	0.1285	1.254	0.107	0.138	0.1695	0.189	0.202	0.212	0.220	0.233	0.2519	0.271	0.284	0.302	0.315	0.326
6	0.1620	0.7888	0.095	0.127	0.1589	0.178	0.191	0.201	0.209	0.222	0.2412	0.260	0.273	0.292	0.305	0.315
4	0.2043	0.4960	0.085	0.117	0.1482	0.167	0.180	0.190	0.198	0.211	0.2305	0.249	0.262	0.281	0.294	0.305
Strand 4	0.232	0.4960	0.078	0.111	0.1424	0.161	0.174	0.185	0.193	0.206	0.2247	0.244	0.257	0.275	0.288	0.299
3	0.260	0.3934	0.072	0.105	0.1372	0.155	0.168	0.178	0.186	0.199	0.2195	0.237	0.250	0.269	0.282	0.293
2	0.292	0.3120	0.067	0.099	0.1318	0.150	0.163	0.173	0.181	0.194	0.2142	0.232	0.245	0.264	0.277	0.288
1	0.328	0.2474	0.063	0.095	0.1264	0.145	0.158	0.169	0.177	0.190	0.2088	0.228	0.241	0.259	0.273	0.283
0	0.373	0.1962	0.056	0.089	0.1205	0.139	0.152	0.163	0.171	0.184	0.2029	0.222	0.235	0.253	0.267	0.277
00	0.418	0.1556	0.052	0.084	0.1153	0.134	0.147	0.158	0.166	0.179	0.1977	0.216	0.230	0.248	0.262	0.272
000	0.470	0.1234	0.046	0.078	0.1099	0.129	0.142	0.152	0.160	0.173	0.1923	0.211	0.224	0.242	0.255	0.265
0 000	0.528	0.09786		0.073	0.1046	0.123	0.136	0.147	0.155	0.168	0.1869	0.206	0.219	0.237	0.251	0.261
Cir. Mils.																
300 000	0.630	0.06902		0.061	0.0964	0.115	0.128	0.138	0.146	0.160	0.1788	0.197	0.210	0.229	0.242	0.253
400 000	0.728	0.05178		0.058	0.0898	0.109	0.122	0.133	0.141	0.154	0.1722	0.192	0.205	0.224	0.237	0.247
500 000	0.815	0.04042		0.053	0.0846	0.104	0.117	0.127	0.135	0.148	0.1670	0.186	0.199	0.218	0.231	0.241
600 000	0.893	0.03452		0.048	0.0804	0.099	0.112	0.123	0.131	0.144	0.1628	0.181	0.195	0.213	0.226	0.236
700 000	0.964	0.02958		0.015	0.0769	0.096	0.109	0.120	0.128	0.141	0.1593	0.178	0.192	0.210	0.223	0.233
800 000	1.031	0.02598			0.0738	0.093	0.106	0.116	0.124	0.138	0.1562	0.175	0.188	0.207	0.220	0.230
900 000	1.093	0.02300			0.0711	0.090	0.103	0.113	0.121	0.135	0.1535	0.173	0.186	0.205	0.218	0.228
1 000 000	1.152	0.02070			0.0687	0.087	0.100	0.111	0.119	0.132	0.1511	0.170	0.183	0.201	0.215	0.225
1 250 000	1.289	0.01657			0.0635	0.083	0.096	0.106	0.114	0.127	0.1459	0.164	0.178	0.197	0.211	0.221
1 500 000	1.412	0.01381			0.0594	0.079	0.092	0.102	0.110	0.123	0.1417	0.160	0.174	0.193	0.206	0.216
1 750 000	1.526	0.01183			0.0558	0.075	0.088	0.098	0.106	0.120	0.1382	0.157	0.170	0.189	0.202	0.212
2 000 000	1.631	0.01035			0.0527	0.072	0.085	0.095	0.103	0.116	0.1351	0.154	0.167	0.185	0.199	0.209

A.	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50	1.60	1.70	1.80	1.90	2.00
B.	0.0022	0.0044	0.0064	0.0084	0.0103	0.0121	0.0138	0.0155	0.0171	0.0186	0.0216	0.0241	0.0270	0.0295	0.0319

For any other frequency *f*, the reactances given in the table must be multiplied by $\frac{f}{60}$

The reactances for diameters of conductors which lie between the sizes given can be found by direct interpolation.

The reactance for any distance *D* not given in the table can be found as follows: let *d* — the nearest smaller distance in the table. Divide *D* by *d* and taking a value of *A* nearest to the quotient find the corresponding value of *B*, which must be added to the reactance corresponding to the size of conductor and distance *d*.

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The effect of the reactance upon the voltage drop in a transmission circuit is dependent very largely upon the power-factor of the circuit. See Figs. 11 and 12, p. 721 and p. 723, *The Electric Journal,* December, 1905.

The e. m. f. induced in a secondary circuit parallel with a current-carrying wire may be read directly from Mr. Fisher's table. If for example the secondary wires be 48 and 18 inches respectively from the current-carrying wire the difference between the reactance values for these distances are to be taken. For No. 10 wire they are 0.326 and 0.281; the difference is 0.045. (This difference is the same for other sizes; thus, for 2 000 000 cir. mils cable, 0.199 less 0.154 is 0.045). This difference must be divided by 2, as we are now concerned with the effect of current in one wire, whereas the table is based on current in two wires. Half of 0.045 is 0.0225. This is the number of volts induced in the secondary circuit parallel with a wire 1 000 feet long carrying one ampere at 60 cycles.

THE WASTE OF TIME*

E. S. McCLELLAND

Assistant Chief Engineer, The Westinghouse Machine Company

WHAT is time? The duration of one's life; the hours and days which a person has at his disposal. Let us look into this matter and see in how many ways we can waste it, and as we pass quickly over various ways, may I ask you to make at least a mental note of the one or more ways you employ in the waste of the most precious thing you have at your disposal.

We are very like to think only of "soldiering" when the waste of time is under discussion. In itself this form is bad enough though in many cases it leads to worse methods. You are all familiar with this way of wasting time, and you are, many of you, so free from so common a method as not to use it, I am sure. We all despise a man thoroughly of whom it is said, "He soldiers during working hours." But soldiering is only one of the many ways of wasting time. Let us see in what other ways we may waste time.

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*An address before The Progress Club at Trafford City, December 6th, 1905.

The most common cause of the waste of time arises from inaccuracy in our work.

Let me lay some stress upon this point. It is one of the greatest sources of loss to the man, the employer and the world. If we are inaccurate in our work, we have wasted not only our own time, but the time of all those who are dependent upon us for the proper prosecution of the work after it leaves our hands. Let us take a concrete example of what will happen in one of the departments if an error is made by only one man.

A drawing is made under the direction of a first-class engineer who pays much attention to the general design; an error creeps in, unnoticed, due to inaccurate work or faulty instructions; the design is finished; it is passed on to the detailer; from the detailer to the tracer; from the tracer to the blueprinter; from the blueprinter to the checker; from the checker to the foreman draftsman; from the foreman draftsman to the chief engineer, and if the error is found, then it goes back to each man, consuming the time of possibly ten men for possibly two or three hours.

Now, suppose the error is not discovered and the drawing goes to the pattern shop, foundry, machine shop, erecting shop; the machine is shipped, and when erected, is found defective and a part must be replaced by one of proper design. Who can measure the waste of time, not only of the man who made the error, but of all those who contributed to finishing the piece?

Think of the possibilities of error in an establishment of the size of ours and try to grasp the fact that the success or failure of the management depends upon every man being accurate in all his work, be the position great or small.

I have not selected the drafting department as an example because it is any more likely to be inaccurate than any other department of the shop. How often do we see the heads of three or four departments called together to consult and devise ways and means to correct a job which has been spoiled, either through improper use of facilities at hand or inaccurate information, or possibly through inaccurate work upon the part of some workman. Do you get the idea I wish to present, that the time of others is wasted by inaccuracies in our work.

How many of us waste not only our own time but that of others by not paying attention to the manner of making our wants known? If we expect the other man to accomplish our wishes, we must convey them in a clear, unmistakable manner, leaving out no detail or thought we may have had upon the matter in hand, and tell it all in the language of the other man, so that he may get the correct meaning.

Now this is one of the most difficult things we have to do, for it calls for a very accurate knowledge of the capacity of every man under our direction. Each man's work must be suited to him. If we do not accomplish this, we waste our time, the man's time, and the cost to the employer can scarcely be estimated in dollars and cents. This relates not only to those in charge of departments or gangs, but to the youngest employe. Get the habit of telling what you want so the other man will know what to do or what to get.

A most important point in the matter of time saving lies in the attention we give to detail. Everything we come in contact with is in the aggregate a mass of detail, and no more fruitful source of time saving can be found than in attention to detail. A man who is to succeed must not only be industrious, but he must have "an almost ignominious love for detail." The success of any institution depends largely upon those who handle the detail. It is for the employer to plan the larger things (and this to a large degree must necessarily be all he can do), leaving the details of his scheme to be worked out by his subordinates. And the result in many cases, is a plan failed of its purpose through the neglect of some employe. What does this cost the employer?

No great man ever became so who did not pay strict attention to detail. You, apprentice boy; you, machinist; you, clerk, note that the slightest error in any detail, be it a bedplate or be it a cotter pin, will cost your employer a loss which you cannot repay by months of labor and effort, and in the end you do not have the confidence of your employer.

It may be hard for you to figure out what it costs you and what it costs your employer. It is hard for me.

It cannot be estimated in money value.

Waste of your time by Idleness, Soldiering, Inattention to Detail, Inaccuracy, Gossiping, Loafing on the Street. All tend to work out in the end to your everlasting discredit.

Young man, the less idling you do, the better off you will be. Benjamin Franklin said: "Dost thou love life? Then do not squander time, for that is the stuff life is made of."

And W. E. Gladstone has said: "Believe me, when I tell you that thrift of time will repay you in after life with a usury of profit beyond your most sanguine dreams, and that the waste of it will make you dwindle, alike in intellectual and in moral stature, beyond your darkest reckonings.

"One of the most important lessons for any man or boy to learn early in life is the economy of time. It is a truth not to be refuted, that lost wealth may be replaced by industry; lost knowledge by study; lost health by temperance or medicine, but lost time is gone forever."

Economy of time will furnish you with a working capital which nothing can rob you of, for capital is nothing more nor less than the abstinence from present gratification for the sake of future needs.

Do not let me hear that you do not have any time to spare. You have all the time there is, and what is more, go hunt out the men in your own community who have done the most for their own and the general good and you will find them to be almost uniformly the overworked class, men wellnigh driven to death, who seem almost swamped with cares, who keep up a ceaseless activity from January to December, and yet, nine cases out of ten, men of this type, busy as they may be, will be found capable of doing a *little more,* and you may rely upon them in their busiest seasons with more assurance than upon the idling man or the dawdling loafer. It seems that the habit of doing increases the power of doing; and that it is far easier for one who is always exerting himself to do a little more for an extra purpose than for him who does nothing to "get up steam." Give a busy man ten minutes to write a letter and he will dash it off at once; give an idle man a day and he will postpone it until tomorrow or next week.

You young men do not perhaps realize that your actions outside of business hours are, in many cases, known to your superior officers and that the way you spend your time has weight with them as to your future.

The small stones that fill up the crevices are almost as essential to a firm wall as the great stones. And so the wise use of spare time contributes not a little to the building up of a man's mind and character, in good proportion and with strength. Above all, do not waste the time given you in loafing either upon the street corner or in any other place that is not elevating. Economize your time. What does it cost a man to waste time in this manner? Such an one will cease to progress; such an one will begin to vegetate; such an one will stand for a time still, and then he will go backward and downward until he is no longer in the race, and over his tomb may well be inscribed, "A failure from waste of time." Time, my young friend, is your most valuable asset; do not waste one precious minute. The man who knows the economy of time will know the art of spending it, just as the man who knows the art of economizing and saving money knows the value of it.

Men must know that in this theatre of man's life it remaineth only to God and angels to be lookers on.—Bacon.

THE USE OF ALTERNATING CURRENT FOR HEAVY RAILWAY SERVICE*

B. G. LAMME

SEVERAL systems have been devolped for using single-phase alternating current for railway service. The great advantage of the single-phase is found, not in the characteristics of the motors themselves, as much as in the fact that with a single overhead wire there seems to be almost no limit to the voltage which can be used. Thirty-three hundred volts has proved to be extremely easy to handle; 6600 volts has also been tried out in a perfectly satisfactory manner; 11 000 volts has been adopted on at least one road, and I have no doubt whatever but that 22 000 volts will be given tests in commercial service within a reasonably short time; in fact, the Swedish Government tests are arranged to cover 18 000 volts on the trolley. It is therefore evident that the single-phase alternating current furnishes the solution of the transmission and trolley problems, for the complication and cost do not increase greatly with increase of voltage.

The success, however, of a single-phase trolley system depends entirely upon the apparatus for utilizing the current. A number of motor systems have been suggested, and some of them have been given a more or less complete trial. Among these may be mentioned the motor-generator type for supplying direct current to motors on the car. This is operative, but means much additional weight and cost, and is practically limited to locomotives. There is also the Arnold system, where a single-phase motor, either synchronous or induction, is operated in con-

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*Extracts from Mr. Lamme's article in the *Street Railway Journal* of Jan. 6, 1906.

nection with pneumatic apparatus on the car. A third system, and the one which has been given the greatest development, is that in which some form of the series commutator type of motor is used. This latter forms what is now known as the single-phase alternating-current system.

It should be borne in mind that it is not any particular merit of the single-phase commutator type motor which constitutes the advantageous feature of the single-phase system, but rather the successful development of such a motor permits the retention of most of the advantages of the present direct-current system while many of its limitations are removed. The motor itself, in its characteristics, closely resembles the direct-current series railway motor, and this is considered one of the principal merits of the single-phase commutator type motor. Having these characteristics, the motor is susceptible of economical speed control, just as in the case of the direct-current motor, but this feature can at once be taken advantage of in an alternating-current system, due to the fact that voltage variation can be simply and economically obtained as soon as we are dealing with alternating currents. The development of such a motor, therefore, at once permits us to use any desired voltage on the trolley system, and this can be transformed to any suitable lower voltage for the motor system, and such voltage delivered to the motor system can be varied economically over any desired range. Herein lies the true merit of the single-phase system and not in any inherent superiority of the motor itself. In fact, the motor itself is superior to the direct-current motor in only a limited number of features, while it is inferior in a number of others.

A single-phase system with commutator type motors possesses the following features of prime importance in heavy railway work, namely, very high voltage with relatively small currents can be used on the trolley circuit; low voltage on the control system and motors; a method of control which varies the voltage in an efficient manner; a type of motor with the speed characteristics of the direct-current motor and therefore susceptible of speed control over the entire range from zero to maximum when used in connection with the above-mentioned voltage control. Finally, the motors and control are connected to a low voltage secondary circuit which can be insulated from the main circuit, if so desired. Another feature of great importance is that the motors can be so arranged that they can be operated in a very satisfactory manner on direct current as well as alternating. This latter feature may not be of great importance, except in the immediate future, but at first it is probable that quite a number of the alternating-current railway systems will have to operate in connection with existing direct-current plants. In this use of the motors on both alternating and direct current, this system is undoubtedly much superior to the three-phase system, even when the motors of the latter are equipped with commutators.

For heavy railway service equivalent to present steam practice, this system commends itself in many ways. Trolley voltages of 6600 or higher now appear to be necessary for such service. Speed control over any desired range, especially for freight service, is of extreme importance and can readily be obtained with this system. With voltage control and commutator type motors, the power consumption at the motors is moreover practically in proportion to the load, and, when running with a given load, at the lowest speeds the power consumption is a minimum. In this feature the single-phase railway equipment resembles the present steam equipments. A further feature of great value from the operating standpoint is that a sudden overload or momentary short-circuit does not mean a shut-down of the system for any considerable period of time. As the trolley system is fed from the lowering transformer simply, without interposition of moving machinery, a short-circuit will have the effect of lowering the voltage temporarily, and as soon as the short-circuit is removed, the voltage can rise to normal and the system is at once operative. In the present alternating-current-direct-current system, however, a severe short-circuit is liable to shut down the system for quite an appreciable period until the sub-station machinery can again be brought into service. Furthermore with the alternating-current-direct-current system the momentary load which can be taken is dependent upon the rotating sub-station apparatus, to a great extent, while, with stationary transformers alone, an enormous overload can be carried for a short time without deleterious effects. The system is therefore a very suitable one for infrequent and violently fluctuating loads. The efficiency of the lowering transformer is quite high over a very wide range, which is not equally true with the rotating machinery, such as is required for transforming from alternating to direct current.

The number of sub-stations and their distribution can be made to conform to the load conditions to any desired extent. For instance, if there is any point where there will be a particularly heavy pull on the system, such as a difficult grade, then a transformer station can be placed at this point.

Another feature possessed by this system is the ability to increase or extend the service with but a relatively small increase in cost. For example, if the service on the road should be doubled or tripled after it is installed, then the number of transforming stations could be doubled or tripled, if desired, these stations being placed between the older stations. In this way the transmission and the trolley systems could remain practically unaffected. Also, an extension of the system at either end could be accomplished in many cases by simply extending the existing lines, without the addition of feeders along the whole system. In other words, the system could be extended very greatly with a cost in the transmission and trolley systems practically in proportion to the extension.

The question seems to be turning now to the comparative economy of the single-phase system and the direct-current system with transforming sub-stations. This is a question upon which it is rather difficult to give any decided answer, as the results would depend on each individual case. The distribution of the losses are so different in the two systems that it is hard to make any comparison unless a rather complete analysis is made. The efficiency of the single-phase alternating-current motor is necessarily somewhat lower than that of a corresponding direct-current motor; also, there is an additional loss in the transforming apparatus on the car. Furthermore, an additional amount of power is required to operate the alternating-current equipment, due to greater weight. The single-phase motors are necessarily somewhat heavier than direct-current motors of same rating, due to a considerable extent to the fact that in the alternating-current motor the steel supporting frame is idle magnetically and therefore constitutes dead weight, while in a direct-current machine the supporting frame or yoke is active magnetically, and therefore constitutes useful material. This, in itself, may represent a difference of 15 per cent. or 20 per cent. in weight between the two types of apparatus. Also, the lowering transformer on the car or locomotive represents an additional weight over the direct-current equipment. The rheostat required on the direct-current system is, however, omitted on a straight alternating-current equipment, although it will be required when the equipment is used for both alternating and direct current. In other features, however, the alternating and direct-current equipments are not so very different in weight. Taking all these facts into consideration, the alternating-current equipment will probably weigh from five per cent. to ten per cent. more than the direct-current equipment, and therefore additional power is absorbed in the operation of the car, due simply to this weight. Therefore, as regards power consumption at the car itself, the alternating-current equipment when running at the same speed as a direct current, requires somewhat more power.

If the system is such, however, that there is very frequent starting, then the alternating-current equipment, using voltage control only, will be more economical during acceleration than will the direct current with its rheostatic and series-parallel combinations. In such cases the difference in economy at full speed may be partly or wholly offset by the better economy of the alternating equipment during acceleration. However, this does not apply to any extent to other service where the steps are relatively infrequent.

Passing to the trolley part of the system, it may be noted that with the very high voltage which can be used with the alternating system the trolley losses can be made very low compared with average direct-current conditions. For long lines, the gain in this part may much more than offset the loss in the equipments, and therefore the two systems may be on a par as regards economy beyond the transformer stations.

In the transforming sub-stations the direct-current system requires either rotary converters or motor generators for transforming from alternating to direct current. In addition, reducing transformers are required for changing from the high-voltage feeder system to the low voltage required by the transforming apparatus. The efficiency of a rotary converter when fairly well loaded is very good, but if the service is very intermittent the average efficiency of the rotary converters may be but little over 90 per cent., if that high. With motor-generators, the efficiency will be from two per cent. to five per cent. lower than with rotary converters. The efficiency of the reducing transformers in these sub-stations is comparatively high. If the single-phase trolley system is fed from transformer stations, then the transformer losses will be present, and it is only the difference in loss due to the rotary converters or motor generators which should be considered. If, however, the trolley voltage should be so high that it can be supplied directly from the generator without transformers, then there would also be a gain in efficiency of the single-phase system due to the elimination of the transformers themselves. Even with transformers in both cases, the single-phase system could use one or more large transformers in place of a larger number of smaller units generally used with rotary converters or motor generators.

It may be suggested that with motor generators the motors could be wound for very high voltage, thus avoiding the use of step-down transformers. This can be done in some cases, but it should be borne in mind that the efficiency of a very high-voltage motor is in general one per cent. to two per cent. lower than a correspondingly low-voltage motor, and thus the gain in efficiency due to omission of transformers will hardly bear consideration.

Going back to the power house, we find that in most cases the single-phase system requires somewhat less total output than the alternating-current-direct-current system with rotary converters or motor generators. This means, therefore, that the efficiency of the single-phase system as a whole is somewhat better than that of the alternating-current-direct-current system; about five per cent. to ten per cent. in most cases. It is this gain in efficiency in the combined system which is important, and not the gain or loss in any particular piece of apparatus. If the single-phase system shows a lower power consumption, with the same service than the alternating-current-direct-current, then it is absurd to criticise the lower efficiency of the car equipments themselves.

Considering next the total cost of such a system, we are again confronted by the fact that different results will be obtained in each individual case, but considering the problem in a general way only, the results indicated below have been obtained. The power house for either system will cost very nearly the same. The power consumption in the single-phase system will average slightly less than that of the alternating-current-direct-current system, but part of the apparatus in the power house will be more costly if the ideal single-phase system is installed. The generators themselves for supplying straight single-phase current should be somewhat more expensive than polyphase machines used with the rotary converter system. This is due partly to the fact that single-phase machines as a rule are larger and heavier than polyphase machines for the same output, and also to the fact that the regulation characteristics of the two systems may be quite different. In the alternating-current-direct-current system the regulation of the generator itself may be comparatively poor and the rotary converters may be compounded to correct for this. In the single-phase generator for railway work, however, all compounding is done at the generator itself, and therefore the machine must have fairly good characteristics in itself. There are also other features in the station which may modify the relative costs somewhat, so that as a rule the power houses for the two systems may be considered as having relatively the same costs. If the power house should represent a comparatively high per cent. of the total cost of the system, then this parity in this one large item may mask to some extent the difference in per cent. in the remaining items. For instance, if in the other items the single-phase system should cost 20 per cent. less than the alternating-current-direct-current, and the power house equipment should represent 50 per cent. of the total cost, then the single-phase system would have an apparent advantage of much less than 20 per cent. of the total cost, while with the power house equipment representing a smaller per cent. of the total cost, the single-phase system shows somewhat better. The actual figures should be looked at and not the per cents.

Beyond the power house the high-voltage transmission line, if one is used, may represent practically the same cost in either system. In the sub-stations, however, if such are used, the single-phase system may have one or more transformers of relatively large capacity compared with a larger number of smaller transformers with the alternating-current-direct-current system. The cost of transformers with the single-phase system should therefore be less. The cost of the rotary converters or motor generators is entirely wiped out with the single-phase system. Therefore this system represents a very considerable gain in cost in the sub-stations. The cost of the buildings themselves can also be reduced as their size can be reduced.

Coming to the trolley system, the high-voltage trolley construction itself may represent a higher cost than the usual direct-current constructions, neglecting feeders. However, when the direct-current feeders are included, the total cost of the direct current part of the transmission system is found to be much higher than that of the high voltage alternating trolley system without feeders. When the car equipments are reached, however, we find the conditions reversed. On account of the construction of the motors themselves, with their thoroughly laminated fields and supporting frames, which represent extra material, the cost is very materially increased over that of the present types of direct-current equipment. Also, the cost of the lowering transformers on the car must be added. If the equipment is to be used for both alternating-current-direct-current, there will be some extra cost due to added switching and controlling apparatus. Therefore, taking everything into account, the cost of the alternating-current equipments is very considerably higher than for corresponding direct-current equipments. However, in general it has been found that this increased first cost of the car equipment does not merely neutralize the gain in other parts of the system, for in the ordinary alternating-current-direct-current system the cost of the electric equipments on the cars represents but a small per cent. of the total cost of the system, and therefore a large per cent. increase in this smaller item will not be equal to a relatively large decrease in cost of some of the larger items. As a rule, therefore, it has been found that the total first cost of the single-phase system is considerably lower than that of the standard alternating-current-direct-current system, the difference depending upon individual conditions. Not considering the power house, in some instances this difference may amount to as much as 30 per cent., while in others it may be as little as 10 per cent.

The above considerations of efficiency and cost have been based on usual conditions of operation as handled by the present alternating-current-direct-current system, but in service corresponding to heavy steam conditions there are other conditions entering which affect the comparison of the two systems. For example, the question of economy of speed control should be considered when it comes to freight service, or in those cases where it is necessary to run for considerable periods at other than the normal speeds. With the present direct-current system, betwen half and full speed, that is, between series and parallel, there is no economical running point, and rheostatic control must be used with corresponding reduction in efficiency. However, with the single-phase system, the number of speeds which can be obtained are directly proportional to the number of voltages which can be supplied from the step-down transformer. As a rule, the number of steps are rather large, and a corresponding number of efficient speeds are obtainable. Therefore the single-phase system, for such condition of service, is much more efficient than the direct-current system, not going beyond the car equipments themselves. Taking the whole system into account, in such cases, the total efficiency should amount to many per cent. better than in the alternating-current-direct-current system. Therefore, in any condition where the direct-current system requires any considerable use of the rheostat for regulating the speed, the single-phase system has the advantage in economy as far as the equipment itslf is concerned. But under conditions where the direct-current equipment does not require a rheostat, the advantage is in its favor. Such conditions, however, would be the exception rather than the rule, in service corresponding to that of the present steam roads.

POWER PLANT ECONOMICS

(Extracts from a paper read before A. I. E. E. January, 1906)

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IN Table I will be found a complete analysis of the losses found in a year's operation of what is probably one of the most efficient plants in existence to-day and, therefore, typical of the present state of the art.

TABLE I.

ANALYSIS OF THE AVERAGE LOSSES IN THE CONVERSION OF ONE POUND OF COAL INTO ELECTRICITY

	B.t.u.	%	B.t.u.	%
1. B.t.u. per pound of coal supplied......	14 150	100.0		
2. Loss in ashes........................			340	2.4
3. Loss to stack........................			3 212	22.7
4. Loss in boiler radiation and leakage...			1 131	8.0
5. Returned by feed-water heater........	441	3.1		
6. Returned by economizer..............	960	6.8		
7. Loss in pipe radiation................			28	0.2
8. Delivered to circulator...............			223	1.6
9. Delivered to feed-pump...............			203	1.4
10. Loss in leakage and high-pressure drips.			152	1.1
11. Delivered to small auxiliaries..........			51	0.4
12. Heating			31	0.2
13. Loss in engine friction................			111	0.8
14. Electrical losses			36	0.3
15. Engine radiation losses................			28	0.2
16. Rejected to condenser.................			8 524	60.1
17. To house auxiliaries..................			29	0.2
	15 551	109.9	14 099	99.6
	14 099	99.6		
Delivered to bus-bar..........	1 452	10.3		

SUMMARY OF HEAT BALANCE

The present type of power plant using reciprocating engines can be improved in efficiency as follows:

Reduction of stack losses....................................	12%
Reduction in boiler radiation and leakage......................	5%
Reduction in engine losses by the use of superheat............	6%

resulting in a net increase of thermal efficiency of the entire plant of 4.14 per cent, and bringing up the total thermal efficiency from 10.3 per cent to 14.44 per cent.

In Table II will be found a tabulation of the relative values of the various items necessary in the maintenance and operation of a power plant. The first column covers a plant with compound condensing reciprocating engines without superheat, and is derived from a year's record of actual costs of a large plant operating with a load-factor of approximately 50 per cent.; load-factor in this case being defined as

$$\frac{\text{Actual output}}{\text{Maximum hour's load}\times 24}$$

TABLE II.

DISTRIBUTION OF MAINTENANCE AND OPERATION. CHARGES PER KILOWATT-HOUR

	Reciprocating Engines	Steam Turbines	Reciprocating Engines & Steam Turbines	Gas Engines Plant	Gas Engines and Steam Turbines
MAINTENANCE.					
1. Engine room mechanical	2.57	0.51	1.54	2.57	1.54
2. Boiler room or producer room	4.61	4.30	3.25	1.15	1.95
3 Coal- and ash-handling apparatus	0.58	0.54	0.44	0.29	0.29
4. Electrical apparatus	1.12	1.12	1.12	1.12	1.12
OPERATION					
5. Coal- and ash-handling labor	2.26	2.11	1.74	1.13	1.13
6. Removal of ashes	1.06	0.94	0.80	0.53	0.53
7. Dock rental	0.74	0.74	0.74	0.74	0.74
8. Boiler-room labor	7.15	6.68	5.46	1.79	3.03
9. Boiler-room oil, waste, etc.	0.17	0.17	0.17	0.17	0.17
10. Coal	61.30	57.30	46.87	26.31	25.77
11. Water	7.14	0.71	5.46	3.57	2.14
12. Engine-room mechanical labor	6.71	1.35	4.03	6.71	4.03
13. Lubrication	1.77	0.35	1.01	1.77	1.06
14. Waste, etc.	0.30	0.30	0.30	0.30	0.30
15. Electric labor	2.52	2.52	2.52	2.52	2.52
Relative cost of maintenance and operation	100.00	79.64	75.72	50.67	46.32
Relative investment in per cent.	100.00	82.50	77.00	100.00	91.20

The values in the other columns have in the main been estimated from the first column, but wherever possible actual data derived from various sources, both domestic and foreign, have been used; but in all cases all values have been reduced so as to make them directly comparable with the first column, and with one another. The values in maintenance and operation of steam turbines are derived from actual costs.

The following heat balance is believed to represent the best results obtained in Europe and the United States up to date in the formation and utilization of producer gas.

ANALYSIS OF THE AVERAGE LOSSES IN THE CONVERSION OF ONE POUND OF COAL CONTAINING 12 500 B.T.U. INTO ELECTRICITY

	B.t.u.	Per cent.
1. Loss in gas producer and auxiliaries	2 500	20.
2. Loss in cooling water in jackets	2 375	19.
3. Loss in exhaust gases	3 750	30.
4. Loss in engine friction	813	6.5
5. Loss in electric generator	62	0.5
6. Total losses	9 500	76.0
7. Converted into electrical energy	3 000	24.0
	12 500	100.0

The combination of gas engines and steam turbines in a single plant offers possibilities of improved efficiency whilst at the same time removing the only valid objection to the gas engine.

A steam turbine unit can easily be designed to take care of 100 per cent. overload for a few seconds; and as the load fluctuations in any plant will probably not average more than 25 per cent, with a maximum of 50 per cent for a few seconds, it would seem that if a plant were designed to operate normally with 50 per cent of its capacity in gas engines and 50 per cent in steam turbines, any fluctuations of load likely to arise in practice could be taken care of.

We have seen that the thermal losses in the gas engine jacket-water amounted to approximately 19 per cent, and as the water is discharged at a temperature above 100 degrees, it can be used to advantage for boiler feed.

The jacket-water necessary for an internal combustion engine will probably be about 40 lb. per kilowatt-hour, assuming that the jacket-water enters at 50 degrees F.; then the discharge temperature will be $50 + \frac{19 \text{x} 12500}{40 \text{x} 100} = 109.4°$ F.

As the steam turbine will require only about 15 lb. per kilowatt-hour, including auxiliaries, it is evident that only 37.5 per cent of this heat or 7.1 per cent of the jacket-water loss can be utilized. The other loss in the exhaust gases of 30 per cent can be utilized either in economizers or directly in boilers or superheaters.

Thus by utilizing the waste heat in the gas engines for the purpose of assisting to make steam for the turbines, there can be saved approximately 37 per cent of the total heat lost in the gas engine.

In the summary of analysis of heat balance it was shown that one can reasonably expect to bring the reciprocating engine plant up to a maximum total thermal efficiency of 14.44 per cent, or possibly with steam turbines using superheat, to 15 per cent.

Referring now to Table 1 it will be noted that in Item 2 the loss in ashes was 2.4 per cent, and the loss to stack in Item 3 was 22.7 per cent; now with the hot gases from the gas-engine exhaust it is evident that the loss in 2 will not exist, and that Item 3 will be reduced from 22.7 per cent to about five per cent as the process of combustion is completed in the gas engine. The total efficiency of conversion of this 30 per cent of heat from the waste gases when used in the turbine plant would then be $15.0+2.4+(22.7-5)=35.1$ per cent.

SUMMARY.

1. The present type of steam-power plant can be improved in efficiency about 25 per cent by the use of more scientific methods in the boiler room, by the use of superheat, and by running the present types of reciprocating engines high pressure, and adding a steam turbine in the exhaust between the engine and the condenser. At the same time the output of the plant can be increased to double its present capacity at a comparatively small cost for turbines and boilers.

2. The steam-turbine plant has an inherent economy 20 per cent better than the best type of reciprocating-engine plant, not so much due to its higher thermal efficiency as to a variety of causes shown in Table II.

3. An internal combustion-engine plant in combination with a steam-turbine plant offers the most attractive proposition for efficiency and reliability to-day, with the possibility of producing the kilowatt-hour for less than one-half its present cost.

TOPICAL CLASSIFICATION OF ELECTRICAL AND RAILWAY ENGINEERING REFERENCES*

GEORGE PARSONS

ENGINEERING.

ELECTRICAL ENGINEERING.

GENERAL.

- STATISTICS, SPECIFICATIONS, ETC.
- MATERIALS.
  - (To be subdivided as required.)
- MEASUREMENT.
  - Systems.
  - Meters.
- THEORY.

GENERATION

(and all parts of Rotating Machines).

- GENERAL.
- POWER PLANTS.
  - (Classified alphabetically or otherwise.)
  - (See also Transformation and Transmission.)
- BATTERIES—Primary.
  - (For storage see Transformation.)
- DYNAMOS AND MOTORS.
  - General.
    - General Tests.
    - Armatures (except Commutator).
    - Bearings.
    - Commutators and Collectors.
      - Brushes.
    - Field Winding.
    - Frame, Field Core.
    - Foundations.
  - Direct Current.
    - Engine Type.
    - Belted Type, etc.
  - Alternating Current.
    - Alternators.
      - General.
      - Inductor.
      - Turbo (Steam).
    - Induction Motors.
    - Series Motors.
    - Synchronous.
  - Pulsating Current.
  - Double Current and Changers.
    - (See Trasformation.)

TRANSFORMATION.

- GENERAL.
- BOOSTERS.
- FREQUENCY CHANGERS.
- MOTOR-GENERATORS.
- RECTIFIERS, "A-C" AND "D-C."
  - Commutating.
  - Electrolytic
- REGULATORS.
  - (See also Transmission and Utilization.)
- ROTARY CONVERTERS.
- SECONDARY BATTERIES.
- TRANSFORMERS.
  - General.
  - Constant Current.
  - Constant Pressure.
  - Series.
  - Induction Coils.
  - Induction Motor as Transformer.
  - Induction Regulator.

TRANSMISSION, CONDUCTORS AND CONTROL.

- GENERAL.
- SYSTEMS.
  - Alternating-Current.
  - Direct-Current.
  - Composite.
- LINES AND CONDUCTORS.
  - General.
  - Over-head (Poles, Arms, etc.).
  - Underground.
    - Conduits (also see Supports).
    - Manholes.
  - Interior Wiring.
    - Fixtures. (See also Retaining and Supporting Devices.
  - Conductors.
    - Insulation for.
    - Wire, Tables, etc.

- RETAINING AND SUPPORTING DEVICES.
  - Messengers.
  - Insulators.
  - Conduits.
- SWITCHBOARDS.
  - General.
  - Ground Detectors.
  - Meters.
  - Protective.
    - Circuit Breakers.
    - Fuses.
    - Lightning Arresters.
  - Switches.
  - Synchroscopes.
- CONTROL AND REGULATION.
  - (See also Transformation and Transmission.)
  - General.
  - Boosters.
    - (See also Direct-Current Generation.)
  - Regulators and Controllers.
  - Rheostats.
  - Storage Batteries.
    - (See Transformation.)

UTILIZATION.

- GENERAL.
- SOLENOIDS, MAGNETS, ETC.
- HEATING.
- ELECTRO-CHEMISTRY.
- MEDICINE.
- LIGHTING.
  - (See also Wiring under Transmission.)
  - Illumination.
    - General.
    - Systems.
    - Arc.
      - (Sub-classify same as Incandescent, if desired.)
    - Vacuum Tube and Vapor.
    - Incandescent.
      - (See Transmission for Wiring, etc.)
      - General.
      - Economy.
      - Illumination.
      - Kinds of Lamps.
      - Apparatus. (See Transmission, Wiring.
      - Photometry.

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* See El. Wld. and Eng. p. 910-912, Vol. 46.

SIGNAL AND INTELLIGENCE TRANSMISSION

- Signals.
  - General.
  - Systems.
  - Call Bells, etc.
- Telegraphy.
  - General.
  - Systems.
  - Wire.
    - Land.
    - Submarine.
  - Wireless.
- Telephony.
  - General.
  - Systems.
  - Switch-Boards.
  - Lines. (See also Transmission.)
  - Protective Apparatus.
  - Other Apparatus.

POWER.

- General.
- Systems, etc.
- Storage Batteries. (See Transformation.)
- Motors and Application of.
  - (See also Generation.)
  - General.
  - Systems.
    - (Alternating and Continuous-Current.)
  - General Machinery.
    - Hoisting, Conveying, etc.
    - Fans.
    - Mining.
    - Shops.
    - Tools and Special Shop Machinery.
  - Traction. (See also Ry. Eng.)
  - General.
  - Systems.
  - Automobiles Electric.
  - Railway.
    - (See Ry. Eng., Generation, etc.)

RAILWAY ENGINEERING.

GENERAL.

LAWS AND THEORY.

SYSTEMS.

(Installations Alphabetically or Otherwise.)

TRUNK.
INTERURBAN.
STREET RAILROADS.

OPERATION.

ACCOUNTING.
DISPATCHING.
LABOR.
MANAGEMENT.

ROUTE.

LOCATION.
GRADE AND SUB-GRADE.
TRACK, BONDS, ETC.
SIGNALS.
MAINTENANCE.

ROLLING STOCK.

CARS AND LOCOMOTIVES.

- Theory.
  - Adhesion, Tractive force.
  - Tests.
- Running Gear.
  - Braking. (See Brakes.)
  - Frames.
  - Suspension.
  - Trucks.
  - Wheels, Boxes, Axles.
- Lighting and Heating.
- Brakes, Hand, Automatic, etc.; Air Brakes,
  - Auxiliary Apparatus.
- Maintenance and Repairs.

SHOPS.

STATIONS AND TERMINALS.

POWER PLANTS AND TRANSMISSION.

(See Generation and Transmission.)

FOR classifying the rapid accumulation of electrical engineering data, the author some years ago devised a system, which, while it has proven quite satisfactory, now shows the need of some change.

The revised form, which appears above, includes the main claims previously held, viz., a logical order dependent on the basis of the generation, transformation, transmission and utilization of energy. Electric railroads is also provided for as a separate subject. In some ways it is closely allied to Electrical Engineering. The system can be made to conform to the Dewey decimal classification.

The Dewey system, commonly used in libraries, divides the whole field of knowledge into ten parts and these are subdivided as far as desired, but the sub-divisions of any one class never exceed ten. To each heading a number is given, the decimal system being employed. The present system is made so that it can be used as a part of the Dewey system, but no numbers have been assigned.

ADVANTAGES OF A TOPICAL CLASSIFICATION

In looking for a note, reference or other bit of information, the common guiding idea is the substance matter of it. The aim of a topical classification is to classify the ideas or the subjects of thought, and not special words. One of the advantages is that articles in any language can be classified with ease and also that persons of any tongue can use the system. The general advantage over the alphabetical arrangement is apparent when one tries to classify such a topic as, "Structural Steel Frames for Alternators of European Design." This would require filing in four to six places in an alphabetical system, while in a topical system it is placed under "Frames" of "Dynamos," requiring only one card.

ACTUAL OPERATION

It is desirable to use the card-index, and the author finds that the common three by five inch or the seven and one-half by twelve and one-half centimeter cards are satisfactory. It is essential that the cards be of uniform height and accurately cut and it is therefore advisable to purchase all cards from one manufacturer and secure a standard which may be duplicated at future dates. Economy of space is of considerable importance to many users of the card-index and therefore comparatively thin cards are advisable. When medium or thin cards are employed, it is generally an economy to use the best grade on account of its writing and erasing qualities and the durability of the edges. A fairly rough surface is desirable if the cards are to be typewritten. Such an unfinished surface will take ink nicely and is most satisfactory for a card for general use. The cost of material is so small that the best cards are the most economical in the end.

For most purposes standard horizontal ruling will suffice. Small clippings may be pasted to the cards and are thus readily handled. Large clippings, curve sheets, small pamphlets, etc., should be placed in a letter file or some vertical file, of dust-proof construction if possible. This file is preferably arranged according to the general scheme so that all actual material on one subject will be in one place. Some prefer to arrange such references and also books in serial or size order, assigning serial or shelf-numbers and making out a card for the card-index, and referring to this number. The author prefers to have all material on a subject in one place so far as the nature and size will permit. i. e., all books of a subject together in topical order on shelves, all clippings, pamphlets, etc., in the same way in vertical files, and cards representing these in proper places in the card index. This may seem trifling at first, but with a few years' growth, the advantages will be apparent and for even a moderate private library it is essential. On account of its convenience one almost always refers to the card index first.

GUIDE CARDS.

The large number of subdivisions requires a corresponding number of guide or tab cards. Experience has shown the following plan to be satisfactory: a main heading such as "Generation" on a "full-cut" or full-width tab of red with white lettering, or a white card with red lettering; the first subdivision, such as "Dynamos and Motors" on a full-cut blue tab with red lettering; the second subdivision, such as "Alternating Current" on a half-cut blue tab with red lettering; the third subdivision as "Alternators" on a third-cut salmon colored tab with black lettering; and the fourth division as "Turbo-Alternator" on a fifth-cut buff colored tab with black lettering.

All this seems elaborate, but the color scheme catches the eye and is a time-saver, fully warranting the initial trouble and expense.

Fig. 1 shows how the cards and lettering appear in actual use except that the colors do not show in the print.

REFERENCE CARDS

The heading for a card should consist of a word, or set of words or symbols, which will readily catch the eye and should be representative of the body of the card.

In commercial indexes there should be a guide card between every ten to twenty reference cards; thus it is seen that after one finds the proper guide card he is dependent on the reference card heading and may have to look on several cards to find the right one. This shows the need of care in selecting the proper heading for reference cards.

As an example take an article on "The Inductor Alternator

Under Load," having to do entirely with power-factor. This card eventually will be placed behind the guide marked "Inductor," consequently the catch word should be "Power-Factor under load," so the mind, being on "Inductor Alternators," will be immediately drawn by the "Power-Factor" phase of the subject.

The heading should be followed on the same or next line by the author's name and then by concise statements in phrases —not sentences—giving a description of the article, data or other note. If this refers to a book or a clipping it should be noted in some particular and standard location. The author has found it convenient to place this in the lower left-hand corner, using symbols as used by others to indicate number of words, photographs, etc., and here is added the journal or book, giving page, etc. Good standard symbols are the following: "T" for tables, "C" for curves, "D" for diagrams, "I" for illustrations and "W" for words. A convenient way is to have a rubber stamp, with blanks following these symbols, and if one is indexing many articles from one publication, its name may be printed as shown on the sample card, Fig. 2.

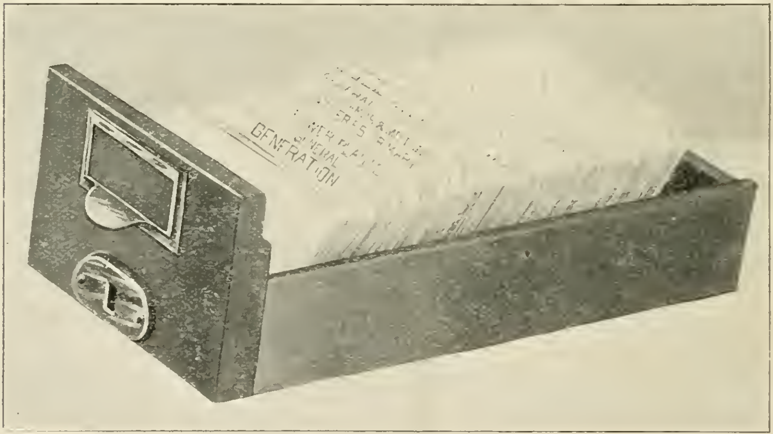
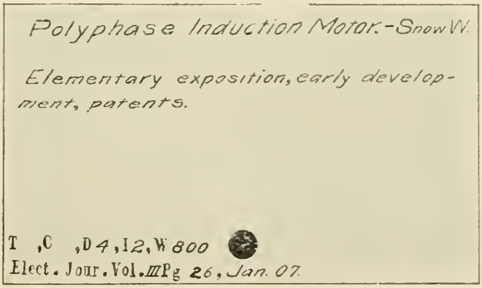


FIG. 1—CARD-INDEX ARRANGED ACCORDING TO THE TOPICAL CLASSIFICATION

Often a note or reference will be found to touch on several subjects. If these are treated in an important manner, each should be given a card and filed in its individual place. Often an article contains remarks which may apply to several allied subjects. Such an article might treat of power-factor of "Alternating Current Machines" and may apply to all alternators, to synchronous motors, etc. In this case it should fall directly behind the next superior heading, or "Alternating Current."

If a reference applies to headings, not in the same part of the index, as "Commutators" in general, it should be filed under one heading as "Dynamos and Motors" and reference should be made on such guide cards as "Rotary Converters," and other machines having commutators in order that common topics may always be found in one place and there alone. This is the simplest solution of an unavoidable difficulty.

Any one who has tried to use the alphabetical index to any technical publication knows the difficulty experienced in finding all articles which have to do with any given topic. This being recognized it was thought that the value of The Electric Journal would be increased if its articles were indexed according to the above topical classification. Such an index, covering in one list the articles in the first two volumes of the Journal, has been prepared and notice of it appears elsewhere in this issue.



Polyphase Induction Motor.-Snow W.

Elementary exposition, early development, patents.

T ,C ,D 4, 12, W 800

Elect. Jour. Vol. III Pg 26, Jan. 07.

FIG. 2—SAMPLE CARD

In conclusion, the author wishes to express his indebtedness to many for the appreciative criticism and suggestions which followed the earlier publication of this subject.

HOW TO MAKE A SLIDE-RULE FOR WIRING CALCULATIONS

E. P. ROBERTS

IN a recent number of the JOURNAL Mr. Y. Sakai gives instructions for the use of the ordinary slide-rule for wiring calculations. Probably most engineers carry these slide-rules with them and can have them marked for wiring calculations. But a very simple slide-rule can be made quite easily and the author has often found it very convenient. This rule was copyrighted by the author in 1894 and a considerable number were made and sold, though it is not now on the market.

The rule is based on the fact that No. 10 wire has a resistance of practically one ohm per thousand feet, and therefore with No. 10 wire 1 000 ampere feet would give 10 volts loss. Also No. 10 wire has practically 10 000 circular mills cross-section, and the size of the wire doubles for each third size larger. For example, No. 7 wire has twice the cross-section (and weight) of No. 10 wire and each size has eight-tenths of the cross-section of the next larger size. The rule may be constructed as follows:

On a piece of paper draw two vertical lines as in Table I, thereby obtaining three columns. Over the first column mark, "Size of Wire"; over the second column, "Volts Loss"; and over both second and third columns mark, "Ampere-Feet and Circular Mils."

In the first column write the size of wire, carrying the numbers to any desired sizes. 500 000 circular mils is generally as large as used.

Then on down this column put each size smaller as 400 000, 320 000, 250 000, No. 0 000, No. 000, etc., down to as small as desired, No. 17 being as small as will be of use in wire calculations.

Then opposite 10 in the first column put 10 in the second column, and 000 in the third and place an arrow-head on the line under the 10 in the first column. Three lines above, opposite No. 7, place 20 in the second column, 000 in the third. The reason for this is evident as No. 7 has twice the number of circular mils as No. 10. Then on the third line, above No. 7, opposite No. 4, write 40 in the second column and 000 in the third. Continue on upwards and also downwards in the same manner. To fill in the unmarked spaces start with No. 8, remembering that No. 8 has eight-tenths the cross-section of No. 7, write 16 in the second column and 000 in the third. And for No. 9 remember that it has 25 per cent. more cross-section than No. 10, write 12 in the second column and 500 in the third. The easiest way to fill in the balance of the spaces in the table is to double or halve, as the case may be, the figures given opposite the numbers 8 and 9 and continue up and down as when starting with the No. 10 size.

TABLE I.

SIZE OF WIRE	AMPERE-FEET AND CIRCULAR MILS	
	VOLTS LOSS	
500	500	000
400	400	000
320	320	000
250	250	000
0000	200	000
000	160	000
00	125	000
0	100	000
1	80	000
2	64	000
3	50	000
4	40	000
5	32	000
6	25	000
7	20	000
8	16	000
9	12	500
10 →	10	000
11	8	000
12	6	400
13	5	000
14	4	000
15	3	200
16	2	500
17	2	000

With the tabulation completed it may be seen that opposite the No. 10 size is the number 10 000, which is approximately the number of circular mils for that size of wire. The same is true for the other sizes. As already pointed out, No. 10 wire will give 10 volts drop for 10 000 ampere-feet, and consequently the figures in the second and third columns opposite any sized wire represent the number of ampere-feet for a calculation showing 10 volts loss.

This table can be converted into a slide-rule by cutting along the line between the first and second columns. Then to use the rule, all that is required is to put the arrow-head on the line below the figures representing volts loss allowable and opposite ampere-feet will be found the size of the wire required. This at first sight may seem to be a lengthy proceeding, but as the basis is exceedingly simple, it will be found that it takes less time to make the rule than it does to read the explanation.

Example:—Suppose a feeder with three branches; branch A, 100 feet long, to carry 20 amperes; branch B, 50 feet long, to carry 100 amperes; Branch C, 200 feet long, to carry 300 amperes; and the feeder, 1 000 feet long, to the junction with the branches. The ampere-feet will evidently be for A, 4 000; for B, 10 000; for C, 12 000, and for the feeder, 840 000. If two volts is the permissible loss in each branch, run the arrow-head down to the line under 2, in the second column, and then opposite 4 000 ampere-feet will be found No. 7; and opposite 10 000, No. 3; and opposite the nearest number to 12 000, No. 2. If 10 volts loss be allowed in the feeder, run the arrow-head to the line under 10 in the second column and it will be seen that 400 000 circular mils is slightly smaller than required for half the ampere-feet. Therefore, at least two 400 000 circular mil wires must be used. The practical man will note that the sizes 7 and 3 are odd sized wires and because of the possible difficulty in obtaining them will use the next size larger or the next size smaller, and in this consideration he will also refer to the insurance rules as to the carrying capacity, providing the wires are to go in buildings. These latter points are, however, independent of the calculations.

The above method is sufficiently accurate for all practical purposes as it is seldom that the amperes can be predicted accurately or that they remain constant within four (4) per cent., which is practically the error of this rule when using soft copper wire.

In order to obtain the resistance of a wire, remember that No. 10 has a resistance of one ohm per thousand feet and the resistance of other sizes will be inversely proportional to the cross-section in circular mils.

To obtain the weight remember that No. 5 solid wire weighs 100 lbs. per thousand feet.

A convenient rule which naturally follows from the explanation given of the slide-rule is as follows:—

If copper wire be used having circular mils equal to the ampere feet, then the loss will be ten volts. The loss for other sizes will be inversely proportionate to the circular mils.

APPROXIMATE RESISTANCE OF COPPER WIRE.*

The accompanying wire table gives the approximate ohms per thousand feet of copper wire B. & S. gauge. It will be noted as the wire becomes smaller, every third size (vertical columns) has double the resistance; also that every tenth size (horizontal lines) has ten times the resistance.

SIZE.	OHMS.			SIZE.	OHMS.			SIZE.	OHMS.			SIZE.	OHMS.		
				No. 0	.1			No. 10		1.		No. 20			10.
				No. 1		.125		No. 11			1.25	No. 21	12.5		
				No. 2			.16	No. 12	1.6			No. 22		16.	
				No. 3	.2			No. 13		2.		No. 23			20.
				No. 4		.25		No. 14			2.5	No. 24	25.		
				No. 5			32	No. 15	3.2			No. 25		32.	
				No. 6	.4			No. 16		4.		No. 26			40.
No. 0000	.05			No. 7		.5		No. 17			5	No. 27	50.		
No. 000		.063		No. 8			.63	No. 18	6.3			No. 28		63.	
No. 00			.08	No 9	.8			No. 19		8.		No. 29			80

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*A new arrangement of the original table published in The Electric Journal, Vol. II., p. 22.

COMMUTATORS AND COMMUTATOR BUILDING*

PHYSICAL AND OTHER QUALITIES DEMANDED BY THE COMMUTATOR

Of the commutator as a whole:

One requirement is that it shall possess such mechanical properties as will be found in a body of the same shape and size turned out of one solid piece of material.

Of the parts, Bars:

(a) The first and most important requirement of the commutator bar is that it shall be made of material possessing high heat conductivity. This is rather different from the popular conception of the commutator bar according to which electrical conductivity is suposed to be the prime requirement. Occasionally the design of the bar becomes such that electrical conductivity becomes a requirement demanding attention, but in the great majority of cases, if the conditions imposed by the requirements of adequate heat conductivity are made, the bar has sufficient electrical conductivity. Copper is therefore universally used for commutator bars on account of its excellent heat conductivity.

(b) Second in importance among the qualities demanded of the commutator bar may be placed a high elastic limit. This is especially important in view of recent advances in high speed commutator work, noticeably in direct-current turbo-generators. In order to obtain a high elastic limit, hard drawn copper is used. For the most extreme requirements, the hard drawn copper is subsequently put through several rolling operations which slightly increase its hardness. Bronzes containing a high percentage of copper have been used to a slight extent for commutator bars where a particularly high elastic limit is desired, but these have not in general given satisfactory results. Hard drawn copper commutator bars should never be exposed to such temperatures as will anneal the copper. Temperatures above 250 degrees C. seriously affect the elastic limit of copper, while at temperatures above 400 degrees C. the elastic limit is greatly reduced.

(c) Commutator bars should gauge very exactly in all parts. The term "gauge" usually indicates "thickness of the bar." The bars should closely approximate the designed gauge at both the thicker and thinner drawn edges as variations in building up are usually in the same direction and so cumulative in effect. It is evident that in a commutator of a large number of bars serious variations in diameter may result from variations in bar gauge. The proper angle between the sides of the bar must also be carefully maintained. For instance, if the gauge of the thicker drawn edge is one mil heavy, the gauge of the thinner drawn edge should be at least one-half mil heavy. A very considerable difficulty is met with in commutator construction due to the fact that in the process of drawing, the central part of the bar draws more readily than the edges. The sides of the bar, instead of being plain surfaces, are curved; and the cross section of the commutator bar therefore becomes, instead of a wedge with plain sides, a wedge with concave sides. This concavity in the sides of the bar is serious if it exceeds one or two mils.

(d) Approximate straightness of commutator bars when received by a manufacturing company is of considerable importance. The commutator bar when ready for assembling must be approximately straight. Practically no bars when received are in this condition as the process of drawing itself gives to the bar slight curvature along the line of its length. Curvatures of large radius can be straightened by laying the bar on a smooth steel plane and carefully hammering the bar at the proper point with an annealed copper or lead hammer. Sharp kinks or bends of short radius resulting from improper packing and careless handling in shipment can never be properly removed from a bar. The shipment of commutator copper therefore demands some attention. Bars of any considerable length should be so packed as to be tightly wedged in the shipping case.

Strips—(a) Proceeding to the commutator strip, the prime thing is the heat requirement. The commutator strip must not be affected by the heat of service. For this reason, mica is the material almost universally used at the present time for commutator strips. The dielectric strength required in the commutator strip is so slight that it need not be considered in design. Contrary to the popular conception, mica in all its various uses is employed on account of its non-deterioration under severe heat, and practically never on account of its dielectric strength.

(b) A second most important quality demanded of the commutator strip is that it shall wear under the brushes so as to keep pace with the wear of the copper bar. The past history of commutating machines shows this to have been a very fruitful cause of trouble. Again and again the fault of high insulation has developed, the danger sign being a blackening of the commutator. Much of the trouble with high insulation can be traced to the use of improper grades of mica in the manufacture of commutator strip. The American (North Carolina and Southern) micas are absolutely unfitted for this work and will usually give trouble in the best commutating machines. The use of India white mica in strip manufacture will also give the trouble of high insulation in all machines except such as have unusually fine commutation. The best micas for commutator strip work are some of the India and Ceylon green micas and the Canadian amber mica. A proper mica for commutator strip manufacture should have an approximate hardness of not more than three as rated by Mho's scale. The liability of high insulation is decreased by splitting the mica into thinner laminations in the manufacture of the built-up mica strip. In many and perhaps most machines the India white mica will give satisfactory results if the strip is built from splittings less than one mil in thickness.

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*An abstract of a talk before the Direct-Current Section of The Electric Club.

(c) The total thickness of the commutator strip is also a factor affecting in a lesser degree the question of high insulation. Thick commutator strips are more liable to develop this trouble. The thickness that long experience in commutator manufacture has shown to give the best all around results is approximately one thirty-second of an inch.

(d) It is of vital importance that commutator strips of built-up mica should not contain an excess of bond. One of the most commonly employed tests of the quality of a sheet of built-up mica is to strike it sharply with the knuckles. Micanite when so struck should give out a dead sound as that of a board; mica which gives a metallic ring when struck with the knuckles almost invariably contains an undue amount of bond and should not be used in commutator work. With built-up mica of the proper quality, no bond (adhesive material) can be squeezed out from the strip during the heating and tightening incident to commutator building.

(e) The commutator strip should be reasonably exact to gauge and any set of strips should average a very close approximation to the designed thickness.

Insulating V-Ring—The prime requisite of the insulating V-ring is that it be not affected by the heat of service. On this account, built-up mica is the material generally used. The V-ring must also have mechanical strength under compression.

Metal V-Ring, Bush and Nut—These parts must possess sufficient mechanical strength. The problem of strength is largely settled by the designer when he determines the material and exact size. Cast iron is the material most generally employed. For large commutators, steel is usually employed. In some small work where economy of space is important, cast brass is often used. The shape of the bush, forming as it does the rear metal V, is an especially difficult form to cast. On account of the uneven cooling of the casting due to its shape, the steel bush is especially liable to shrinkage holes and spongy structure. This difficulty is also experienced to a certain extent in iron castings. On this account it is customary to sand-blast steel and iron castings of these parts, carefully examining the same and rejecting such as show indication of shrinkage spots or spongy structure. A second and obvious requirement of these commutator parts is accurate fit. This is usually attained by care in the machining operations.

POINTS TO BE NOTED IN MANUFACTURE

It is not intended here to go into any detailed account of the steps of commutator manufacture. The following points are, however, worth noting:

The "baking" of the commutator, as it is commonly termed, might more properly be called "adjusting of strips." With mica strips of the proper quality, the baking operation is not made either to expel moisture or to get rid of an excess of bond. The sole reason for "baking" a commutator is to adjust the mica strips to the inequalities of the copper. If this is not done during the process of manufacture, the strips will adjust themselves under the conditions of service. The amount of adjustment in each strip is small, usually about one mil. These adjustments, however, are in the same direction, being equivalent to a shrinkage of the strip and are therefore likely to produce a loose commutator.

For a similar reason to those given above, the mica V-ring should be heated when in final position, producing a like adjustment. The principle of adjustment of built-up mica to inequalities in the metal surface depends on the fact that, when the bond is sufficiently softened, built-up mica will flow under pressure. The temperature to which a commutator should be heated for adjusting strips and V-rings is that at which the dissolved gum of the bond is in its most fluid state. For a shellac bond, this temperature is 125 to 150 degrees C.

THE
ELECTRIC JOURNAL

VOL. III. MARCH, 1906 NO. 3.

Tube Illumination

The law of inverse squares, so familiar in connection with common forms of lamps, does not apply unless the light be emitted from a point. New conditions, both mathematical and practical, are encountered when the source of light is a luminous tube.

An ideal economical illumination should be based upon the following conditions:

(1) For a given expenditure of energy a maximum quantity of light impinging upon the sensitive portion of the eye.

(2) Approximate uniformity of illumination throughout different parts of the area to be lighted.

(3) A moderate variation in the intensity of light from different directions at each point.

Neglecting the efficiency of the source itself, the first principle requires a maximum opening of the pupil of the eye as well as the best forms of reflectors and reflecting surfaces; the light entering the eye being that reflected from the object in view itself and not the quantity of light entering the eye when observing the original source of light. Experience shows that any intense spot of light, however small, as for instance, an arc lamp, or even the filament of an incandescent lamp, causes a contraction of the pupil of the eye in order to protect the sensitive portion of the eye. The presence of bright spots in the field of vision keeps the opening of the pupil normally more or less contracted, even though the eye only occasionally looks directly at the bright spot, and thus diminishes the effective illumination from the object in view. Conversely, with a given illumination, the absence of the arc and to some extent incandescent lamps too, will greatly increase the amount of light utilized by the eye.

Furthermore, the presence of dazzling point lights reduces, at least temporarily, the sensitiveness of the eye itself, thus again reducing the effectiveness of the illumination.

In the Cooper Hewitt mercury vapor lamp, the source of light is distributed uniformly over a very large area and enables the pupil of the eye to remain wide open, so that a maximum use can be made of the actual amount of light. Furthermore, the normal intensity of the tube itself is so low that after looking steadily at the lamp the eye is not dazzled, and can readily see less brilliantly illuminated objects. The net result of these conditions is that the vapor lamp has a great advantage in efficiency over arc and incandescent lamps, quite aside from the relatively small value of watts required per candle power.

A substantially uniform illumination throughout a space is, of course, important, since its minimum strength—not the average strength—is the criterion. Uneven distributions not only give a low minimum, but the contrast with the brighter parts still further reduces the actual usefulness of the light at the minimum point. Difficulties of this kind are usually overcome by distributing a large number of point illuminants. This method is expensive, both in increasing the wiring and the cost of lamps, since small units are usually more costly in proportion than large units. In the matter of distribution, the Cooper Hewitt lamp, especially the longer tube, has an advantage in that the law of inverse squares, stating that the intensity of the light is inversely proportional to the square of the distance from the source, holds only with sources mathematically a point. The length of the Cooper Hewitt tube is such as to cause the intensity of the light to decrease much less rapidly with distances from the lamp than with an arc, a consideration which easily leads to the question of shadows.

An object illuminated by light from a mathematical point, which substantially represents an arc lamp, casts a very deep sharp shadow. In the case of the tubular light, since the source is distributed over such a considerable space, no definite shadow will be found. It is true that an object may obstruct light even from a Cooper Hewitt tube, but a spot in shadow from one portion of a luminous tube is lighted from other parts; the net result being that with the Cooper Hewitt light, no sharp or deep shadows are produced, except close behind large objects. This point is found to be of great practical value. It is obviously necessary to have a difference in the strength of the light coming from different directions upon any surface; otherwise no detail could be seen, since every part would reflect the same amount of light as every other part. On the other hand, if the light from one direction, predominates very much over the light from other directions, very deep shadows will be cast, within which there will not be light enough to see details clearly. Practically there is little difficulty found except in special cases from too uniform a distribution of light, for no method of artificial illumination has yet been found which will give anything like uniformity in all directions at all points. Nearly all commercial installations have too great a contrast in shadows, rather than too small. The results obtained by the use of the Cooper Hewitt tube seem to be nearer the ideal mean for most work than those from any other artificial light.

It should be remembered in this connection that in all cases where accurate judgment has to be made of colors, and in many other cases where conditions are extreme, other features than those discussed predominate in the choice of the best form of lighting.

Percy H. Thomas

Telephone Engineering

The wide scope of the work of the electrical engineer is admirably illustrated in the paper by Mr. Carty before the February meeting of the American Institute of Electrical Engineers. Mr. Carty is the chief engineer of the New York Telephone Company, and the engineering work of what is probably the most notable telephone installation in the world is under his direction, and he is recognized as one of the foremost among telephone engineers.

Among many people the idea of telephone engineering covers an electrical acquaintance with transmitters, receivers, batteries, magnets and switchboards. The minor importance which Mr. Carty assigns to purely electrical features is indicated by the single sentence with which he dismisses this phase of the subject. "A good knowledge of electrical laws and a fair acquaintance with electrical machinery may be gained in our electrical schools and graduates from them are, as a rule, proficient in these matters." He then proceeds to take up other factors, the existence of which is not generally recognized.

As an example of the real problem in telephone engineering the case of New York City is taken. The first question to decide is the period of time which should be taken and for which the construction is to be planned. This includes the expectations of growth, the probable number of lines which will be required, the distribution of lines in different parts of the city and surrounding territory, the size and number of central offices, which in turn are dependent upon the volume of service and its distribution throughout the day in different parts of the city. Closely related to these matters is a study of the switchboard conditions. This again is closely related to the method of charging for service and the general business policy, as a flat rate or a measured service will bring different requirements upon the switchboard, both as to its type and its capacity. In considering the type of cable not only must the proper standard of transmission be maintained but the type should be selected which will secure the best mechanical conditions for hauling in and out of ducts and the construction which, both electrically and mechanically, will require the minimum of attention and maintenance. We are reminded that telephones do not deal with infinitely small currents to the exclusion of others, as a 10 000 line switchboard requires a storage battery with a safe discharge capacity as high as 2 000 amperes.

The telephone engineer comes in contact, in one way or another, with various branches of electrical engineering and with mechanical construction, operating methods, business policy and human nature.

The same kind of foresight which he must exercise in planning for the future is called for in other branches of electrical work. How to plan for the conditions and demands which will arise in ten, or fifteen, or twenty years when the number of telephones in service is doubling in about three years is no simple problem. Possibly the problem of the future has been forced upon the telephone engineer with greater emphasis than upon the lighting and power branches of electrical engineering. It is not infrequently the case that power house and distributing circuits are soon overloaded and it is then found that no intelligent provision for increase in capacity has been made, plans do not admit of expansion, and reconstruction is the costly penalty of past errors.

One of the important conclusions to be drawn from Mr. Carty's paper, aside from the broad scope of telephone engineering work is the importance of imagination in engineering and the value of intelligent foresight.

Chas. F. Scott

Fuses

Mr. Harvey's article in this issue deals with "Fuses," a class of auxiliary electrical apparatus of very extended and important use. Any installation of electrical apparatus, whether simple or complex, should be protected by a device that will automatically open the circuit under an abnormal condition which would damage other apparatus. The fuse is the most elementary form of device for doing this work and in its simplest construction, is a comparatively inexpensive link in the circuit, which is itself destroyed. Fuses were first made of metals with a low melting point, such as lead, but later it was found that especially for large capacities, other metals, such as copper and aluminum, were better adapted, on account of the less volume of material to be melted, when the fuse was blown.

The cartridge, or enclosed fuse, very effectively takes care of the objectionable features attending the blowing of an open fuse—chief of which are the spattering of melted metal and the attendant fire hazard.

For higher voltages, the ordinary form of fuse is not well suited on account of the wide spacing of the terminals necessary to insure that the arc will not hold over when the fuse is blown. To provide for this kind of service, the expulsion type of fuse was developed. In this way, a comparatively compact device can be made. The same end is accomplished by the use of the magnetic blow-out principle, but on account of the added expense, this is applied only in special cases, such as in replacing large fuses for car service.

The other form of device for automatically protecting apparatus is the circuit breaker. Its operation differs from that of the fuse, chiefly in that it is instantaneous in action, whereas the fuse has a time element. Circuit breakers for low voltages are of the air type, but for high voltages, the general practice is to use the oil type of circuit breaker.

For currents up to about 600 amperes, either fuses or circuit breakers may be used, but for larger currents, circuit breakers are always used.

For currents within the range of application of fuses, the question of whether a fuse or a circuit breaker should be used depends upon a great many conditions. A fuse has a time element and its first cost is low, but each time the fuse blows, there is the expense of renewal. The circuit breaker is instantaneous in action and can be set to open at different currents within its range, and though its first cost is higher than that of the fuse, it performs its functions of opening the circuit many times without additional expense.

On acount of the very great losses which may be caused by overloads or short-circuits, the function of the automatic protective device is an exceedingly important one and too much care cannot be exercised in its selection. It is, however, gratifying to know that a properly designed fuse or circuit breaker can be depended upon to open the circuit under the most severe conditions of overload or short-circuit.

T. S. Perkins

Central Station Profit

It is a curious thing that the vast business of selling electrical current has developed so few men with the keen instinct for making money which is so characteristically American. Most of the men in central station work are hard against the problem of selling their current at a profit. It has been claimed that fully one-half of the central stations in the United States are not making money. Indeed the business in its daily succession of a short time lighting load at a comparatively high price succeeded by a longer interval with a comparative absence of income, resembles in its instability, nothing so much as a summer hotel, which has an advantage in that its fixed charges can be lessened during the season of no profit.

The general solution of the difficulty lies not in raising the peak load of lighting but in raising the hollow of low business in daytime. Power loads must be found, and without reference to the charge for lighting service the price of power may usually be anything that will net a profit over the cost of additional coal. In too many stations the power business is in the hands of machine operators instead of men of a commercial instinct for bargaining and selling; too few central stations analyze the costs and profits of the various parts of their business as is the custom of large commercial houses. The awakened interest in the whole subject, brought about by the work of the Co-operative Electrical Development Association, ought to be productive of results, and the large cash prizes offered by them for helpful papers ought to stimulate the business study of this condition.

J. H. Smith

ELECTRIC RAILWAY ENGINEERING

CONTROL OF CARS AND TRAINS OPERATED BY DIRECT CURRENT*

WILLIAM COOPER

IN the problem of control only the operation of direct-current motors as applied to the propulsion of trains will be considered. As the series-wound motor is the only one possessing the proper characteristics for the work, this is the only type of motor that will be considered. As to the method of transmitting the power of the motor to the driving wheels of the car or locomotive, only one will be considered, that in which the motion of the motor maintains a constant relation to the motion of the driving wheel. This implies that the motor must start from rest, since the car or locomotive starts from rest, and increase its speed as the speed of the car or locomotive is increased.

The problem of control, then, consists in starting the motors from rest and accelerating them to full-speed in a given period with a minimum expenditure of energy and the greatest possible uniformity of motion. These two conditions are fulfilled only when the impressed e.m.f. is increased at a uniform rate. This condition can only be secured by manipulating the field of the generator which furnishes the current to the motors or by having an infinite number of steps in the regulating rheostat. It is obviously impossible to secure either of these conditions in practice, and thus the nearest approximation possible under the given conditions is the aim of the control designer.

If the size and number of motors for any given case have been decided upon, the method of control to a certain extent may be determined by the operating conditions. The first point which should be considered is the maximum allowable variation in the torque of the motors during acceleration. The average torque during acceleration must be a certain amount in order to fulfill the conditions laid down. From this it is evident that the accelerating force will be a certain constant amount upon which there will be superimposed another amount which will be composed of a succession of impulses in the nature of blows of greater or less intensity, depending upon the number of impulses or the number of steps in the regulating resistance. Since these impulses can not be eliminated entirely they should be made small enough to give the desired smoothness of operation, whether the consideration be the strength and durability of the apparatus or the comfort of the passengers. The consideration of this phase of the control problem is quite apart from the manner of manipulation and the apparatus used. It is evident in any case, that these impulses must be small enough to be within the strength of the apparatus. In locomotives for hauling freight this is a very important consideration, but in the control of motors for driving single cars it does not enter into the consideration to any great extent, though it will affect the life of apparatus.

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*This is the third of a series of articles on Electric Railway Engineering. The first article appeared in the January, 1906, issue.

In general the variations in the torque of the motors during acceleration should not be more than twenty per cent. between maximum and minimum. Assuming this as a basis for the design of the control, the next step is the determination of the number of resistance steps required. If there are two motors to be controlled a series-parallel method of control should be used. From the torque curve of the motor may be found the current input required to give the acceleration necessary to maintain the schedule as laid out.

This will be the average current input of the motors. As there will be a variation in the current flow to the motors the maximum will be somewhat greater than this and the minimum somewhat less. Assume that the maximum will be ten per cent. greater and the minimum ten per cent. less. That is, the currents corresponding to ten per cent. more and ten per cent. less torque are to be taken as the maximum and minimum currents. With this information the last step of resistance to be cut out with the two motors in series can be calculated and also the last step with the motors in parallel. This is done by a consideration of the saturation curve and the ohmic resistance of the motors. For instance, suppose that it is found that the allowable variation in the current is fifty amperes, say from three hundred to three hundred and fifty amperes. Assume that the saturation curve shows an increase of six per cent. with this increase of fifty amperes in current, and that the ohmic resistance of the motor is one-tenth of an ohm. With two motors in series the total resistance will be two-tenths of an ohm. Assume that just prior to cutting out the last step of resistance the voltage impressed on the two motors was five hundred and fifty. An increase of six per cent. of this will be thirty-three volts, and ten volts will be absorbed by the resistance of the motors due to the increased current. If a further allowance be made for the resistance and self-induction of the car wiring and connections, of say seven volts, a total of fifty volts may be impressed upon the motors in one step without exceeding the allowable increment of current. Fifty volts drop with three hundred amperes flowing gives a resistance of one-sixth of an ohm as the resistance of the last step.

By the same method the resistance of the other steps can be calculated and likewise the number of steps. Having determined the number and value of the resistance steps required for the control of the motors in any given case, the next step is to determine the method and kind of apparatus to be used.

METHODS OF CONTROL

There are several methods of control in use, depending upon the number of motors employed and the conditions under which they operate. The following are the principal ones, although there are some modifications even of these:

(a) Rheostatic.
(b) Series-parallel.
(c) Series, series-parallel, parallel.

Rheostatic—The rheostatic method, as the name implies, consists in placing resistance in the circuit with the motor or motors to regulate the impressed electromotive force. This method can be used irrespective of the number of motors employed by connecting them in parallel and in series with the regulating resistance. A resistance common to all the motors may be used or each motor may have its own resistance. This method of control is not commonly employed except with a single motor or where simplicity of apparatus is of more importance than economy of operation.

Series-Parallel—The series-parallel method is by far the most common in use and can be employed where the number of motors used is a multiple of two. With this method the motors may be arranged in any combination such that there will be two motors in series at the start, the final arrangement being all in parallel. By this arrangement two economical operating speeds are obtained, that of two motors in series or approximately one-half speed and all motors in parallel or full speed.

It is also possible to use this method when three motors are employed by connecting the three motors in series and then in parallel. In this case the operating speeds will be one-third and full speed.

Series, Series-Parallel, Parallel—The series, series-parallel, parallel method can be used only when the number of motors employed is four, or some multiple of four. With this method the motors are arranged, first, four in series, then two in series and two in parallel and then all in parallel. By this arrangement three economical operating speeds are obtained, one-fourth, one-half and full speed.

By economical operating speeds is meant speeds at which the motors may be operated without external resistance in the circuit.

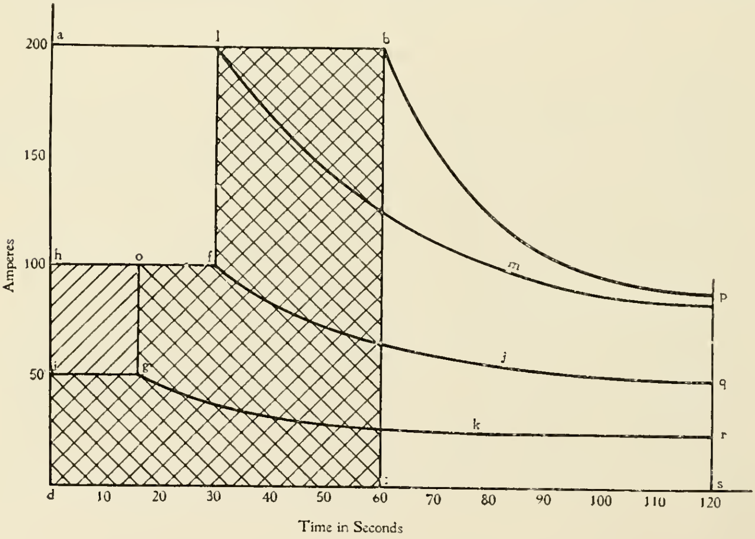


FIG. 1

The curve, Fig. 1, illustrates the difference in the amount of energy required to start and operate the motors when arranged in different combinations. Assume that a car or locomotive is equipped with four motors and that it will require fifty amperes per motor to start and accelerate it up to a certain speed in sixty seconds, the speed at the end of that time being that which corresponds to fifty amperes in the motor with the full voltage impressed upon its terminals. If the motors are operated all in parallel the energy will be represented by the area *a-b-c-d* or, assuming a line voltage of 600 volts, 7 200 000 watt-seconds. If the motors are operated two in series, two in parallel, then four in parallel, the energy will be represented by the area *h-f-l-b-c-d* or 5 400 000 watt-seconds, which shows a saving of twenty-five per cent. energy input. If the motors be operated four in series; two in series, two in parallel; four in parallel, the energy will be represented by the area *i-g-o-f-l-b-c-d,* or an additional saving of 6.25 per cent. of the total input.

This illustrates the saving that may be made in starting and accelerating to full speed, but if the running speed is to be less than full speed, the saving will be still more marked. Assume that half-speed is desired. With the motors in parallel it will be necessary to discontinue cutting out resistance at the end of thirty seconds. The current will then fall off on the line *l-m*, reaching approximately the same value at the end of, say one hundred and twenty seconds, that it would have if the resistance were all cut out. The energy input for the whole time will be represented by the area *a-l-p-s-d*. The total energy is the mean height of this area multiplied by the time and line voltage. The energy taken from the line for continuous running will be twice as much with motors in parallel as with the motors in series.

If, however, the motors are operated in combinations of two in series, all external resistance can be cut out at the end of thirty seconds and the current will fall off along the line *f-j*, being one-half the amount of *l-m*, with the speed remaining the same. Again if the motors can be arranged in combinations of four in series and a speed of one-fourth full speed is required, the current consumption will be only one-fourth of what it would be if the motors were all operated in parallel.

RESISTANCE CONNECTIONS

Having determined the method of control and the number of resistance steps required, the next point to be decided is the manner of connecting the resistance to the switching apparatus. There are two methods of doing this, the series and the parallel methods.

The Series Method—This consists in arranging the total amount of resistance in one group or in several groups with the different groups all connected in series at the start. The variation of the resistance in the circuit is accomplished by short-circuiting sections of it progressively.

The Parallel Method—This consists in connecting different sections of resistance in parallel. The value of the resistance is thus decreased as each section is connected in, until finally the whole resistance is short-circuited. The two methods are illustrated by Figs. 2 and 3, which show a single motor with rheostatic control. Either method, however, is applicable to any number of motors or any combination of motors or different combinations of resistance connections may be used. Each of these methods has advantages and disadvantages.

The series method has the advantage of having all the resistance available for heat radiation when operating on the first point of the control. It has the disadvantage of requiring larger and heavier switches as each switch, when it is closed, short-circuits its section and must carry the whole current passing to the motors. This means that each switch must be of the same capacity as the final short-circuiting switch in the other method.

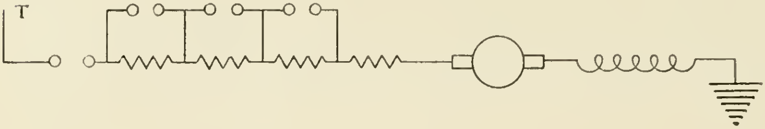


FIG. 2

The parallel method has the advantage of using smaller switches, but the disadvantage of requiring more capacity in the resistance. There is still another method of connecting the switches when using series resistance, as shown in Fig. 4.

This method has the disadvantage as compared with that shown in Fig. 2 in that if the last switch remains closed for any reason the resistance is all short-circuited, while in the other cases only one section is short-circuited.

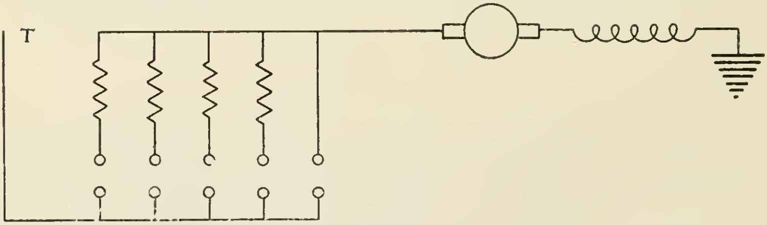


FIG. 3

MANIPULATION OF CIRCUITS

If rheostatic regulation is to be used the manipulation of the circuits is a simple matter, as it is only necessary to arrange the circuits as shown in any of the three diagrams, Figs. 2, 3 or 4, and provide means for cutting out the resistance. If, however, the series, parallel or series, series-parallel, parallel method is used, the matter becomes more complicated. That is, the manner of making the transition from series to parallel must be considered. By calculating the resistances as already indicated, it will be found that

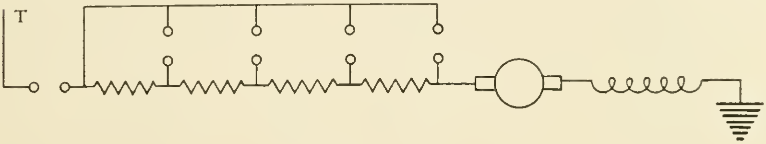


FIG. 4

more resistance must be used with the motors in series than is desirable when the motors are thrown in parallel after running up to the series connection with the resistance all cut. The difference in these values must be determined and arrangements made either to leave a certain amount of the resistance short-circuited or to cut it out entirely.

There are three methods used in changing the motors from the series to the parallel connection.

(a) Shunted motor.
(b) Open circuit.
(c) "Bridging."

The Shunted Motor or Short-Circuited Motor Method—This method is shown in Fig. 5 and consists in arranging the motors in series with each other and in series with a resistance. After the

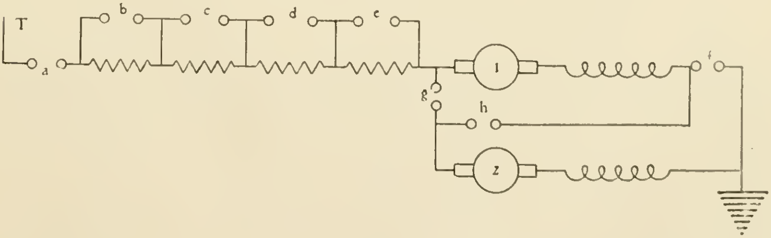


FIG. 5

resistance has been cut out with the motors in series, certain of the resistance switches are again opened, thus reinstating a portion of the resistance. Immediately following this the second motor of the series is short-circuited by connecting the first motor directly to "ground." The second motor is then connected in parallel with the first and in series with the resistance. Referring to the diagram the controlling switches are indicated by the letters *a-b-c-etc.* The circuits are established as follows: First by closing switches *a* and *h*. Then switches *b-c-d* and *e* are successively closed, thus cutting out the resistances and putting the motors in series without resistance. The switches *c-d* and *e* are then opened and *f* closed. At the same time *h* is opened and *g* closed in the order named. This establishes the motors in parallel with the resistance *c-d* and *e* in the circuit. The resistances *c-d* and *e* are then successively cut out leaving the motors in parallel without resistance.

The Open-Circuit Method—The open-circuit method is very similar to the shunted motor method except that the switch *a* is opened while the other changes are being made. The reason for opening switch *a* is to prevent a sudden rise in voltage on the first motor due to its being in circuit for a short time with the resistance that is afterwards put in with both motors.

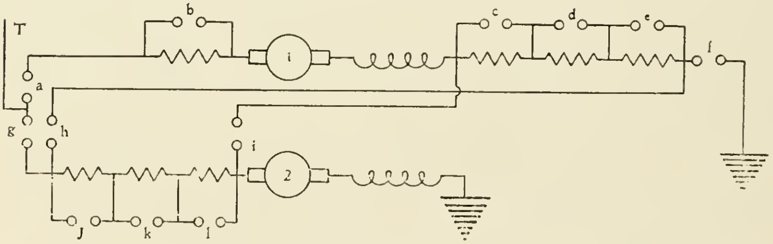
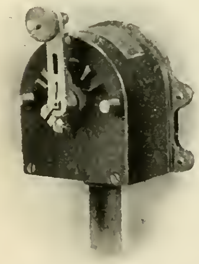


FIG. 6

The "Bridging" Method—This method is quite different from the others in that the current is not at any time cut off either motor nor is either motor subjected to any sudden rise in voltage. This method is shown in Fig. 6 and consists in first arranging the motors in series and in series with three different groups of resistance. The different sections of resistance are cut out progressively by the different switches shown. After the resistance is all cut out with the motors in series and they are operating two in series across the line, the resistance, or a certain portion of it is connected in parallel with the motors also across the line. As this resistance is divided into two parts and the connections between the two parts are connected between the two motors, it follows that there is the same drop in voltage across each portion that there is across each motor or one-half of the line voltage. Under these conditions the connections between the motors may be broken provided the resistance connections be maintained. Referring to the diagram the circuits are as follows:

Starting from the trolley, switches *a* and *h* are closed, thus putting the motors in series with all resistance in circuit. The switches *b-c-d-e—j-k* and *l* are closed consecutively and then switch *i* is closed. After switch *i* is in switches *c-d-e-h-j-k* and *l* are opened. The circuit is now through switches *a-b* and *i* and the two motors. If *g* and *f* then be closed there will be a circuit established from the trolley through the resistance to "ground" by the way of switch *i*. There are thus established two circuits through the switch *i*, which are in opposite directions. The current will flow in the direction of the circuit which has the preponderance of current. If the currents in the two circuits be equal there will be no current passing through the switch *i* and it may be opened without causing any increase or decrease of current in the motor circuits.

After this is done the resistance switches are progressively closed as before, thus cutting out the resistance in the motor circuits until the motors are operating in parallel across the line without resistance. Thus the motors are started in series with resistance and brought up to full parallel without any greater change of impressed voltage than that derived from cutting out the various steps of resistance one at a time.

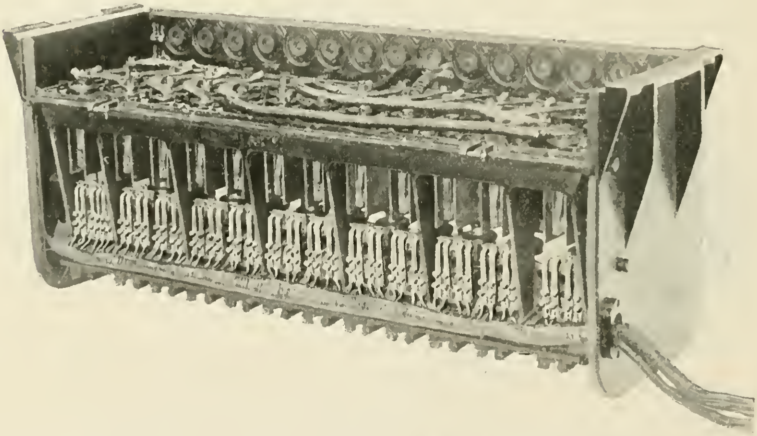

MASTER CONTROLLER

This scheme can be used with four motors operating four in series; two in series, two in parallel; four in parallel through the whole cycle without at any time having the torque changed more than that due to the cutting out of one resistance step.

KIND OF APPARATUS USED

Up to this point only the different schemes of control and the different arrangements of the resistances have been considered together with the method of calculating the total amount of resistance necessary and the value of each step. Having determined the number and value of the different steps of resistance and the method of varying the resistance, the next consideration is the apparatus for manipulating the circuits. In the discussion of the diagrams the term "switch" has been used to designate a piece of apparatus used to close and open a circuit. This may be a contact finger rubbing on a segment of a drum or it may be any sort of a device which is suitable for carrying and breaking the required amount of current.

Apparatus either manually operated or automatic in its operation could be devised that would fulfill any of the conditions laid down in the diagrams. Therefore, when an apparatus is designated as hand operated or automatic it does not signify that any particular method of control is contemplated. The conditions under which the apparatus is to operate will determine to a great extent the kind of apparatus that should be used. In general, automatic acceleration is a very desirable thing to have. In some cases it is a necessity. In other cases the complication involved is not warranted. Again the apparatus used may involve remote control. This again may involve either hand or automatic acceleration. The distinction between hand and automatic acceleration should be clearly understood. Manually operated apparatus cannot give automatic acceleration nor can automatic acceleration be produced with manually operated apparatus. Manually operated apparatus may be either remote or local control, but automatic acceleration can only be produced by apparatus over which the operator has no

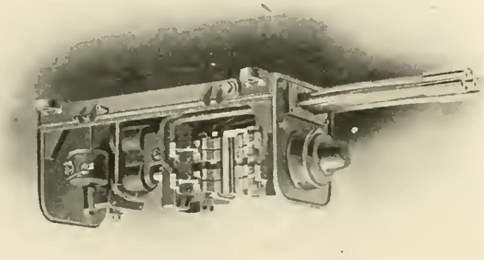


SWITCH GROUP FOR USE WITH 2-200 HORSE POWER MOTORS, WITH COVER REMOVED SHOWING INTERLOCK FINGERS AND CONTROL WIRINGS control after it is once set in motion. This implies, although it does not necessarily mean, remote control.

On this basis there are but two kinds of control apparatus possible:

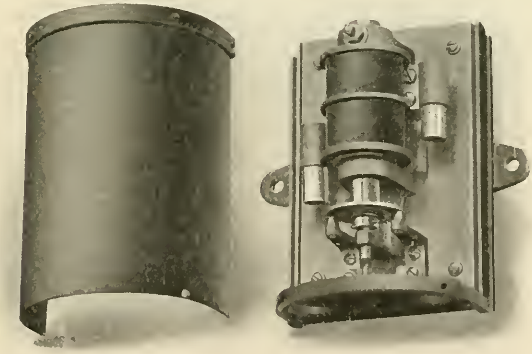
(a) Hand or manually operated, and

(b) Automatic.



REVERSE SWITCH FOR 2-200 HORSE POWER MOTORS

The most common form of hand control is by the ordinary drum controller. These controllers have been built in a great number of different forms and sizes suitable for all sizes of motors from the smallest to the largest. They have given good results and have done wonderful work, but they have serious defects and limitations, not the least of which is that the personal equation of the operator is pre-eminent. That this is a serious defect is shown by the numerous devices that have been applied to drum controllers to limit the speed of manipulation. These devices are called automotorneers, such terms indicating a desire to make the control automatic, or at least prevent improper manipulation by the motorman.



SERIES LIMIT SWITCH WITH COVER REMOVED, SHOWING PLUNGER AND CONTACT DISC

This switch governs the progressive action of the unit switches so that the progression is arrested whenever the current exceeds a certain predetermined limit, thus insuring a practically constant current per motor during acceleration.

MULTIPLE UNIT CONTROL OR AUTOMATIC ACCELERATION

As the name implies, this method contemplates the automatic control of a number of units connected in multiple. Each car of a train is considered as a unit and is controlled and actuated as a unit entirely independent of all the other cars in the train.

FUNCTIONS AND REQUIREMENTS

To fulfill these requirements the driving motors on each car must at all times do a certain predetermined proportion of the work of acceleration and full speed running irrespective of their speed-torque characteristics. That this condition may be fulfilled the controlling apparatus on each car must control the motors on that car independent of the controlling mechanism of the other cars.

The insertion and the elimination of the resistance constitutes the chief function of the control apparatus. The greater the number of increments into which the resistance is divided, the smoother the acceleration, provided they are eliminated in the proper progression and at the proper time. To fulfil this condition it is necessary that the current input of the motors be controlled for each motor independently.

In a multiple-unit control system, the current input of the motors should be regulated on each car with absolute independence. This must be done by the main control apparatus on each car, acting independently of the main control apparatus on the other cars of the same train, the mechanism of the main control being started and stopped by the action of the auxiliary control.

As there are two different combinations of the motors which give maximum operating efficiency, it is desirable that either should be available for continuous operation, and for ordinary service, these only.

As the trains operate in either direction it must be one of the functions of the main control to reverse the direction of rotation of the motors.

ESSENTIAL FEATURES

To accomplish these operations it is necessary that the auxiliary control should fulfill the following conditions:

(a) A definite arrangement of the circuits for each direction of rotation of the motors.

(b) A definite arrangement for the series combination of the motors.

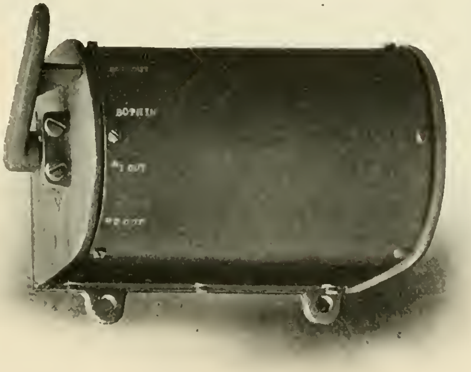
(c) A definite arrangement for the multiple combination of the motors.

(d) The ability to arrest the transitions at any stage between zero and full speed, or to bring the main control back to zero from any position.

ADDITIONAL FEATURES OF VALUE

In addition to these essential features of multiple-unit control the following features are of great value in the practical operation of a system.

If the current supply to any car of a train, or to all of the cars, fails, it is desirable that the main control switches automatically return to the zero or off position.



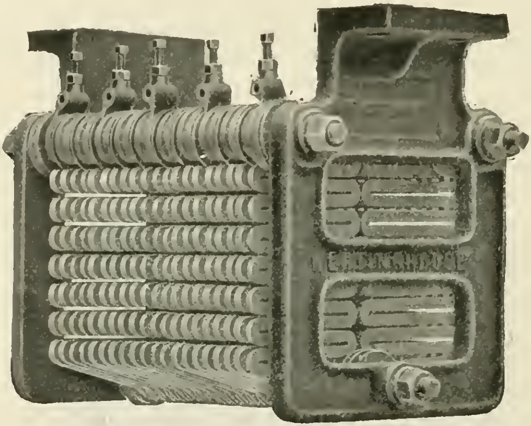
MOTOR CONTROL CUT-OUT FOR 2-200 HORSE POWER MOTORS ARRANGED SO THAT BOTH MOTORS TOGETHER OR EITHER MOTOR SEPARATELY MAY BE CUT OUT

Upon the restoration of the current supply, the main control should automatically be brought into action and supply power to the motors through the regular progression up to the point indicated by the arrangement of the auxiliary control, irrespective of what that arrangement may be. It is further desirable that the main control of any car upon which the current is cut off should not be brought into action by the auxiliary control. It is desirable that in an emergency the main control can be caused to operate through the regular progression in order to connect the motors in the multiple combination, as when so connected one will generate current and send current through the other as a motor and serve to stop the train if the power is off and the brakes fail to act.

This same arrangement is also useful in testing the apparatus when the current supply is not cut off.

AUXILIARY CONTROL DEFINED

The auxiliary control is in the nature of a telegraph system along which messages are transmitted. These messages indicate to the main control that it is to perform a certain duty, but have no direct control over the performance of that duty. The construction of the mechanism of both the main and auxiliary control must be such, however, that there will be no failure of the main control to perform the duty assigned to it.



TYPE OF GRID RESISTANCE USED WITH SWITCH GROUPS.
SINGLE FRAME READY FOR MOUNTING.

SAFETY DEVICES

As the mechanism of the control system may sometimes fail to perform its proper functions, and as the motors may sometimes behave improperly, certain safety devices are desirable adjuncts to the system. These must be provided as a part of the auxiliary control in the form of certain interlocks on the different parts of the main control apparatus, so arranged that if the different parts do not perform their proper functions the auxiliary control will become inoperative. Certain overload attachments must be provided as parts of the main control, so that if a "short-circuit" or an overload exists, the auxiliary control will become inoperative. and cause the main control to return to the zero or "off" position, or cause the circuit of the main control to be opened by a suitable circuit breaker.

NOTES ON SUPERHEATED STEAM

J. R. BIBBINS

DOES it pay to use superheated steam in steam power plants, i. e., can a user of it be assured that he will not only save a definite percentage of his coal pile, but that he will also come out ahead when all capital charges are deducted from the gross saving?

In order to determine the ultimate commercial value of superheat, not only the gross saving in water or coal must be taken into account, but also the standing expenses or fixed charges upon the investment, and for maintenance of the superheater equipment. In the following balance sheet the most important items are mentioned:

CREDIT	DEBIT
Saving in coal per unit of time.	Extra coal required for firing superheater.
Reduction in size of piping and boiler equipment required.	Extra labor required.
Reduction [with high velocity steam] of abrasive action due to entrained moisture.	Taxes and interest on investment in superheater, extra piping, and in extra building space.
	Depreciation and maintenance.

It is true that all these debit items are not usually taken into account, and in fact capital costs are frequently omitted altogether from the cost of power. In this case the net showing made by superheat will be much greater. The argument for superheat in nine cases out of ten ends with the statement that a saving of 10 per cent in steam consumption can be secured by employing 100 degrees superheat with a coil superheater installed in the boiler setting. Some builders even go so far as to say that this type of superheater does not take any extra coal for firing, as does the independently fired superheater. This statement is evidently misleading, and the efficiency of transmission of heat in the one type should be practically the same as in the other. If the superheater is installed in the path of the hot gases of the boiler, either the capacity of the boiler is reduced or a hotter fire must be carried to make up for the heat put into the superheat.

In spite of the excellent results obtained through the use of high or even moderately superheated steam in steam motors, particularly steam turbines, it is an unfortunate fact that practically no reliable data exist by which the above question can be *definitely* answered.

IMPORTANT POINTS INVOLVED

The effect of superheat upon the steam consumption of reciprocating engines (See Fig. 1) is in general similar to that with turbines, viz.: for a given horse power less water is required according to the degree of superheat. This is due to the fact that the volume of a pound of steam increases with the superheat, as well as its internal heat energy, and also that the extra heat in the steam serves to prevent condensation and other heat losses in the cylinder, or at least to reduce them. This extra heat also defers to a later stage in the expansion cycle the "dew point," i. e., the point where the steam becomes saturated and moisture begins to form.

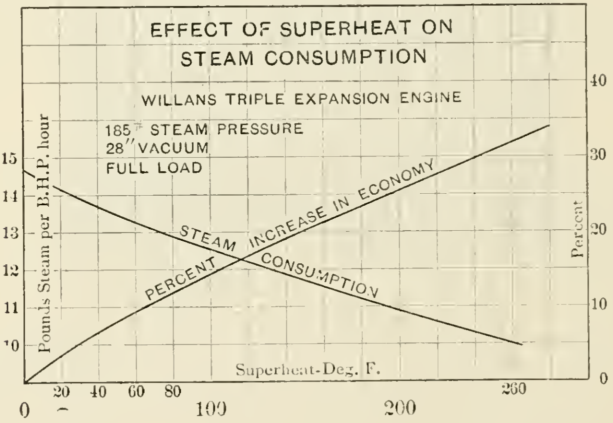


Fig. 1.

Steam expanding from 150 pounds pressure to 28 inches vacuum has approximately 23 per cent. moisture in it as it passes to the exhaust, *provided that no heat is taken in or given out* during its passage through the engine. This is the ideal method of steam expansion (known as *adiabatic*, Greek—meaning "a barrier").

In the reciprocating engine the ideal expansion is departed from, due to many complex and variable losses such as condensation and re-evaporation at the beginning and end of the stroke respectively. But it is believed that *in the turbine*, as these losses do not occur, *the steam expansion is practically adiabatic*, to which may be attributed to a considerable degree its higher inherent economy.

Now, if extra heat be put into the steam initially, by superheating, this extra heat renders a direct service; in the engine by

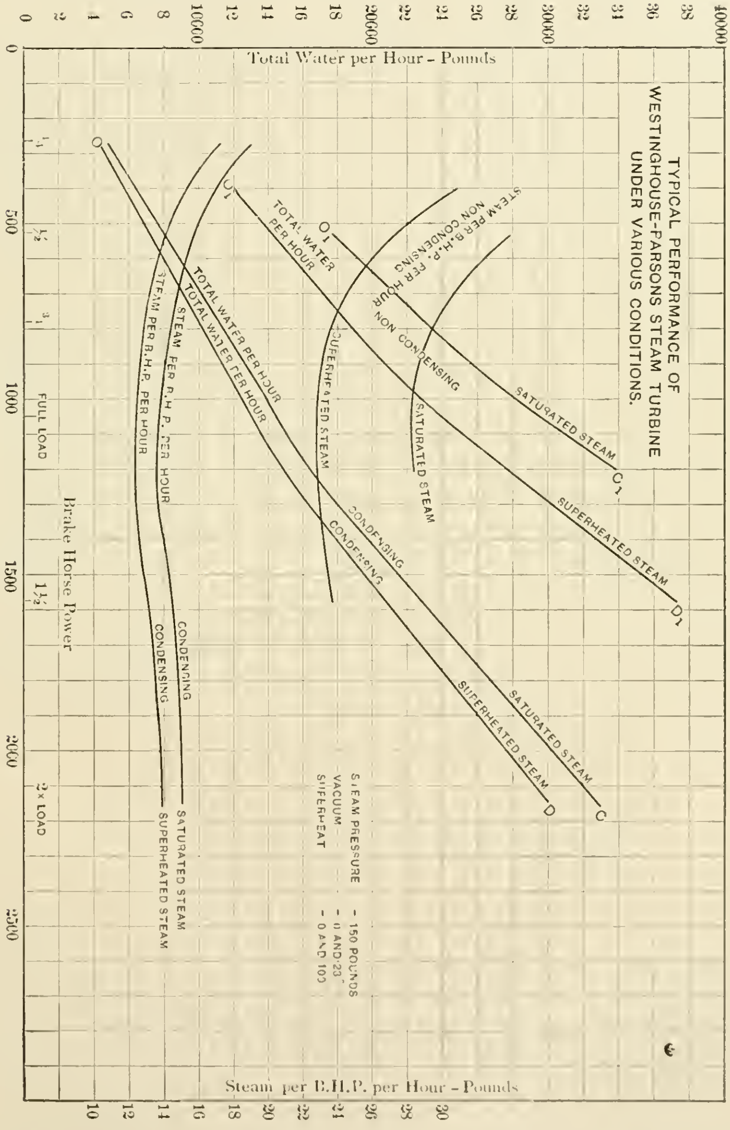


Fig. 2.

compensating for some of the heat losses; in the turbine by retarding the "dew point" further on in the expansion range. It thus occurs that with sufficient initial superheat the entire 23 per cent. of moisture which results from expansion may be compensated for, and dry steam may be secured through the whole turbine.

The beneficial effects of superheat in the turbine are of somewhat different character than those in the engine. In the latter severe thermal losses occur, as noted above; in the turbine the losses are probably more of a mechanical nature due to the friction of the steam moving at high velocity over the internal superficies exposed to it. The denser the steam and the higher its velocity, the greater is the resulting friction. This is an important point especially in high velocity turbines. In the Parsons type of turbine, where the steam velocities are kept down to a low point, (400 to 600 feet per second) superheat is not found to be so essential.

Owing to the disastrous effect which steam friction has upon the economy of a turbine using high velocity steam the use of superheated steam, as well as the highest possible vacuum is frequently insisted upon. Being of much lower density than saturated steam—in fact approximating the state of a perfect gas—superheated steam greatly reduces the internal friction in the machine; with a commensurate increase in economy. A test* by Dr. Lewici of Darmstadt, shows how serious this friction may become in a 30 hp single stage turbine disc running first at atmospheric pressure and then in vacuum. The turbine was driven by a calibrated motor and, in order to bring it up to running speed, power was required as follows, expressed in per cent. of the capacity of the turbine. This is disc friction alone—not jet and bucket friction:

RESISTANCE.

	Atmosphere.	19.6″ Vacuum
(A) Dry saturated steam . . —	11% (3.3 hp)	5%
(B) Superheat 300° C.=572° F.—	6.25%	2%
Decrease in friction per 100° F., (% of A) . . . —	7.5%	10.5%

RESULTS—STEAM CONSUMPTION

Turbine Tests—The effect of superheat in a Westinghouse-Parsons turbine is shown by Fig. 2. The line *OC* represents the total water per hour at different loads with saturated steam. The line *OD* represents the total water per hour at different loads with superheated steam. The divergence between these two lines, therefore, represents the effect of superheat, viz.: *for a given degree of superheat the water saved is in direct proportion to the load*, or in other words, the percentage saving is practically constant at all loads. This latter point is well brought out by Fig. 3. The lines *A, B,* show the decrease in steam consumption per brake hp for different loads and degrees of superheat; they are practically parallel. For this reason, the per cent. increase as shown by the line *OX* is practically constant for any load. This test shows that for 50 degrees superheat the percentage reaches 5 per cent, for 100 degrees, 10 per cent. and for 150 degrees, 15 per cent. Above 100 degrees, this test and other tests show that the percentage increase falls off somewhat, similarly to the overload line at the point *X1*.

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*Stodola, "Die Dampf Turbinen."

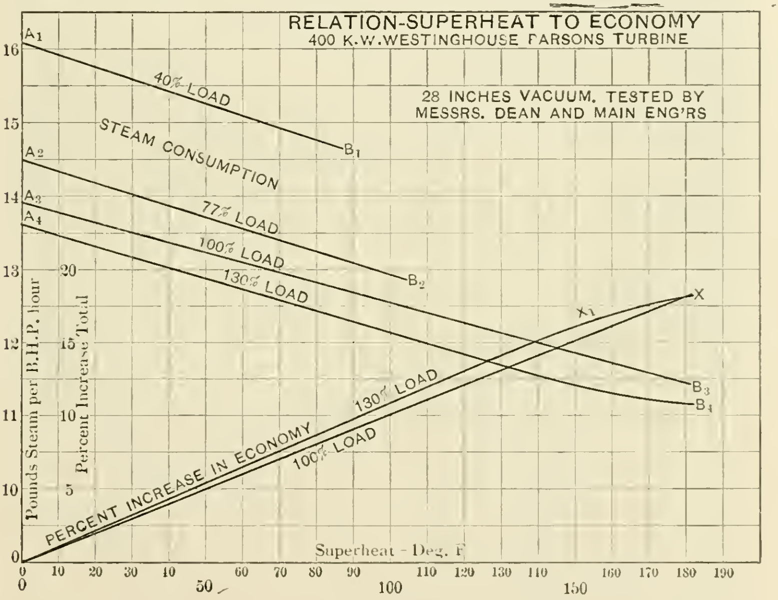
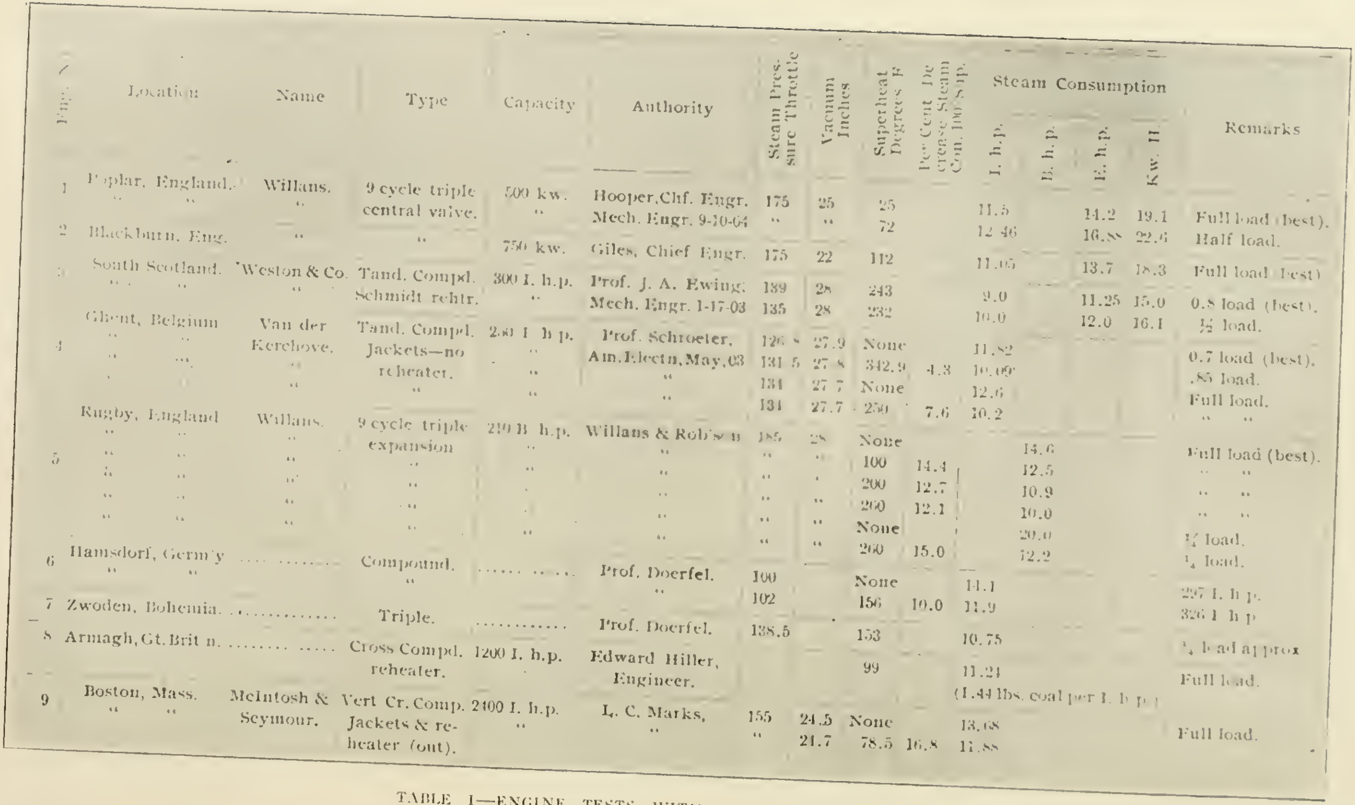


FIG. 3.

Engine Tests.—In order to show the results of superheat in the engine we have compiled the data in the following table:

Engine 3 shows the best results, viz.: nine pounds of steam per indicated hp hour, but it must be borne in mind that this was obtained with 28 inches vacuum and 243 degrees superheat. This may be considered as high an efficiency as has ever been obtained in engine work, but even under these extremely favorable conditions the unit consumed 11.25 pounds of steam per electrical hp hour; assuming a generator efficiency of 95 per cent. it consumed 10.7 pounds per brake hp hour.

By way of comparison, note that the turbine, Fig. 3, gave a brake water rate of 11.15 pounds with 180 degrees superheat. By



Eng. No.	Location	Name	Type	Capacity	Authority	Steam Pressure Throttle	Vacuum Inches	Superheat Degrees F.	Per Cent Decrease Steam Con. 100 Sup.	Steam Consumption				Remarks
										I. h.p.	B. h.p.	E. h.p.	Kw. H.	
1	Poplar, England.	Willans.	9 cycle triple	500 kw.	Hooper, Chf. Engr.	175	25	25		11.5		14.2	19.1	Full load (best).
	" "	"	central valve.	"	Mech. Engr. 9-10-04	"	"	72		12.46		16.88	22.6	Half load.
2	Blackburn, Eng.	"	"	750 kw.	Giles, Chief Engr.	175	22	112		11.05		13.7	18.3	Full load (best)
3	South Scotland.	Weston & Co.	Tand. Compd.	300 I. h.p.	Prof. J. A. Ewing:	139	28	243		9.0		11.25	15.0	0.8 load (best).
	" "	"	Schmidt rehtr.	"	Mech. Engr. 1-17-03	135	28	232		10.0		12.0	16.1	½ load.
4	Ghent, Belgium	Van der	Tand. Compd.	250 I. h.p.	Prof. Schroeter,	126.8	27.9	None		11.82				0.7 load (best).
	" "	Kerchove.	Jackets—no	"	Am. Electn, May, 03	131.5	27.8	342.9	4.3	10.09				.85 load.
	" "	"	reheater.	"	"	134	27.7	None		12.6				Full load.
	" "	"	"	"	"	131	27.7	250	7.6	10.2				" "
	Rugby, England	Willans.	9 cycle triple	210 B. h.p.	Willans & Rob'son	185	28	None			14.6			Full load (best).
	" "	"	expansion	"	"	"	"	100	14.4		12.5			" "
5	" "	"	"	"	"	"	"	200	12.7		10.9			" "
	" "	"	"	"	"	"	"	260	12.1		10.0			" "
	" "	"	"	"	"	"	"	None			20.0			¼ load.
	" "	"	"	"	"	"	"	260	15.0		12.2			¼ load.
6	Hamsdorf, Germ'y	....	Compound.	....	Prof. Doerfel.	100		None		14.1				297 I. h.p.
	" "		"		"	102		156	10.0	11.9				326 I. h.p.
7	Zwoden, Bohemia.	....	Triple.	....	Prof. Doerfel.	138.5		153		10.75				¾ load approx
8	Armagh, Gt. Brit'n.	....	Cross Compd. reheater.	1200 I. h.p.	Edward Hiller, Engineer.			99		11.24				Full load.
										(1.44 lbs. coal per I. h.p.)				
9	Boston, Mass.	McIntosh & Seymour.	Vert Cr. Comp. Jackets & reheater (out).	2400 I. h.p.	L. C. Marks,	155	24.5	None		13.68				
	" "			"	"	"	21.7	78.5	16.8	11.88				Full load.

TABLE I—ENGINE TESTS WITH SUPERHEATED STEAM

increasing the superheat 63 degrees the economy would probably have increased by at least 5 per cent, which would bring the turbine water rate to 10.6 pounds per brake hp, which fully equals that of the engine.

Note engine No. 5, a *triple expansion engine* of the Willans central valve type. With 200 degrees superheat the steam consumption was 10.9 pounds per horse power at full load and with high pressure and high vacuum. Referring again to the turbine, with 20 degrees extra superheat the steam consumption would have been about 10.9 pounds, practically the same as the Willans engine.

Column 10 in this table shows the per cent. decrease in steam consumption, i. e., the increase in economy due to 100 degrees of superheat, assuming that these quantities are proportional to the superheat. The average is in fair agreement with results from turbines, but the wide variations show that the gross saving due to superheat in engine work *varies largely with different designs.*

It must be borne in mind that such results as these obtained with reciprocating engines are seldom maintained in regular service owing to the lack of care and general deterioration. On the other hand, we have reason to believe that the economy of low velocity turbines *is not subject to serious impairment in service;* we know that the depreciation is extremely low.

RESULTS—COAL CONSUMPTION

The effect of superheat on the coal pile is quite a different matter than its corresponding relation to steam consumption; and unfortunately very little data is available.

TABLE II

TEST* ON 300 I.H.P. TANDEM COMPOUND ENGINE

DATA:	
Lancashire boilers.	
Schmidt separately fired superheater.	
Steam coal, heat units per pound	14 300
Superheater coal, heat units per pound	12 800
Average evaporation lbs. water per lb. coal	8.7
Average quantity superheated, lbs. steam per lb. coal	24
Temperature at superheater	800° F. = 440° Supht.
Superheat lost, delivered to reheater	177°
Superheat lost in transmission	50°
Temperature at engine throttle	580° F. = 220° Supht.
RESULTS:	
Coal used per lb. of steam (total)	= 0.157 lbs.
Coal required to superheat one pound of steam 440° F.	= 0.417 lbs.
Coal required to superheat per 100° F.	= .0005 lbs.
Coal required to evaporate one lb. of water at 140 lbs. presure	= .115 lbs.

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* Prof. J. A. Ewing. Engine No. 3, Table I.

220° Superheat at Engine:

Per cent. of total coal for evaporation........................ 73.5%
Per cent. of coal required for superheating.................. 26.5%

100° Superheat at Engine (Estimated from above):

Per cent. of total coal required for evaporation.............. 92.4%
Per cent. of coal required for superheating.................. 7.6%

TABLE III

TEST† ON 522 B.H.P. THREE-CYLINDER TRIPLE EXPANSION ENGINE.

Data:

160 pounds steam pressure.
Superheated to 600° F. = 230° superheat.
Vacuum 26 inches.

Results:

Fuel per hour, saturated steam.................................. 1193 lbs.
Fuel per hour, superheated steam......................... 833 lbs.
Fuel per hour in superheater............................ 173 lbs.

Total.. 1006 lbs.

Saving......................87 pounds = 19% = 8.25% per 100° superheat
Fuel for evaporation, per cent. of total.................. 83%
Fuel for superheating, per cent. of total................. 18%

TABLE IV

TEST* ON 254 I.H.P. MUSGROVE-CORLISS ENGINE, CONDENSING, FLUE TYPE SUPERHEATER

Southport, Eng., Electricity Supply Company.

Average Superheat = 85° F.	Without suprhtr.	With suprhtr.	Saving per cent.
Steam per i. h. p. hour..........................lbs.	16.30	13.58	17%
Steam per kw. hour...... .... "	29.27	24.24	
Coal per i. h. p. hour............................lbs.	1.84	1 60	16%
Coal per kw. hour................................ "	3.40	2.86	

* Reginald S. Downe—Proc. Municipal Elec. Assn. of Gt. Britain.

These data appear to indicate a general saving at the coal pile in reciprocating engine plants. With turbines we may *only infer* that the saving is perhaps smaller, *but more definitely assured.*

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† R. K. Morcom, of Belliss & Marcom, builders of engine.

COST AND MAINTENANCE OF SUPERHEATERS

The approximate cost of some typical superheater equipments is shown below:

TABLE V

APPROXIMATE COST OF SUPERHEATERS

Type	Construction	Cost, $ per 1000 lbs. steam per hour							Cost superh'r per kw. plant capac. assuming 20 lbs. steam per kw. hr.	
		Without setting			With setting				Without setting	With setting
		Rating		Per 100°	Rating			Per 100°		
		100°	200°		100°	150°	200°			
		$	$	$	$	$	$	$	$	$
Flue or sep. fired.	Steel tubes cast iron flutings.				100			(1) 100.00		2.00
						115		(1) 76.80		1.54
							130	(1) 65.00		1.30
Sep. fired.	do.		116.66	58.33			134	(2) 67.00	1.16	1.34
Flue	Plain steel tube.	72.00		72.00	82.80			(2) 82.80	1.44	1.66
Sep. fired.	C.i. with flutings.		146.66	73.33			168	(2) 84.30	1.47	1.69
		Average		67.88	Average			72.65	1.36	1.59

(1) Including freight and erection.

(2) Estimated extra cost settings, dampers, flues, etc., 15%

The following table gives some data relative to the maintenance cost of superheaters. This data is all based upon results from the Schwörer (German) type, similar to the Foster (American):

TABLE VI

COST* OF MAINTAINING SUPERHEATERS OF THE SCHWORER TYPE, INCLUDING REPAIRS TO PIPING AND BRICKWORK

P'nt No.	In Service. Yrs.	In Service. Hrs. per day.	Avg. steam pressure.	Av. superh't.	Superh'tr. elements No.	Superh'tr. elements Lgth.	Av. Cost Repairs per Year. Superheater.	Av. Cost Repairs per Year. Per element.	REMARKS.
			Absolute.	Deg. F.		Feet.	$	$	Position of superheater.
1	8	11	100	190.5	12	10.5	71.40	5.95	Direct fired.
2	5	12	107		4	9.8	14.09	3.69	Directly behind fire bridge.
2-a	10	11	78		2	8.2	11.90	5.45	“ “ “ “
3-b	10	11	114	105.2*	6	9.0	0	(*4.00)	Behind first flue,
4	11	12	85	76-156	6	9.8	8.33	1.39	“ “ “
5	6	24	100-156	155-121	8.10	6.7	5.95	0.66	“ “ “ (fire tube boiler)
6	7	11	171	131-205			0	(*4.00)	Directly behind fire bridge.
Avg.	7.7	13.5	114	155-8				2.45	Conclusions: 100° superheat - $2.3 per element per year.
			Avg. including estimates (*)					3.59	100° superheat - 0.19 per lineal foot per year.

*Avg. temperature of gases at superheater, 716 to 842 F.

No information is at hand regarding the capacity of the plants or the rating of the superheaters, but you will observe that the cost of maintenance expressed in dollars is extremely low. In plants Nos. 4 and 5, which have been in service from seven to eleven years, no repairs have apparently been made. As this is somewhat improbable we have estimated them as shown in parenthesis. Covering a number of plants which have been in service for many years, and coming from an evident authority on the subject, these data are valuable in showing that the depreciation in a properly constructed superheater is much smaller than is generally thought.

SOME PROPERTIES OF SUPERHEATED STEAM

From steam tables we observe that the temperature of saturated steam increases gradually with the pressure carried, likewise the heat energy expressed in B. t. u. per pound. A British thermal unit is the amount of heat required to raise one pound of water one degree F. at freezing point; we therefore say that the specific heat of water is one or unity. In order to raise steam one degree above its temperature of saturation, or in other words, to superheat it one degree, it has been found by experiment that less than one heat unit is required, or in other words, that the specific heat of superheated steam is less than unity. The classical experiments of Regnault made some fifty years ago are, curiously enough, accepted to a certain extent to this day. He found that in order to raise steam one degree above saturation point 0.48 B. t. u. was required, that is, that the specific heat of superheated steam was 0.48. His determinations, however, were only made at about atmospheric pressure,

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* Otto Berner-Verin Deutsch, Ingineure.

TABLE VII.

PROPERTIES OF SATURATED AND SUPERHEATED STEAM.

Pressure, lbs. per sq. inch, abs.	Temperature steam degrees F.		Superheat Degrees F.	Total heat, B. t. u. per pound		B. t. u. per pound added in superheat.
	Saturated	Superheated		Saturated Steam.	Superheated Steam	
1	2	3	4	5	6	7
100	327.6	377.6	50	1181.9	1214.5	32.6
		427.6	100		1254.0	72.1
		477.6	150		1298.5	116.6
		527.6	200		1348.4	166.6
120	341.	391	50	1186.	1220.7	34.7
		441	100		1261.2	75.2
		491	150		1307.1	121.1
		541	200		1358.5	172.5
140	352.9	402.9	50	1189.5	1225.4	35.9
		452.9	100		1267.4	77.9
		502.9	150		1315.0	125.5
		552.9	200		1367.6	178.1
150	358.3	408.3	50	1191.2	1227.5	36.3
		458.3	100		1269.4	78.2
		508.3	150		1318.0	126.8
		558.3	200		1370.6	179.4
160	363.4	413.4	50	1192.8	1229.5	36.7
		463.4	100		1272.0	79.2
		513.4	150		1321.0	128.2
		563.4	200		1375.0	182.2
180	373.	423	50	1195.7	1234.0	38.3
		473	100		1278.0	82.3
		523	150		1327.0	131.3
		573	200		1383.6	187.9
200	381.7	431.7	50	1198.4	1237.6	39.2
		481.7	100		1283.0	84.6
		531.7	150		1333.0	135.6
		581.7	200		1390.0	191.6

NOTE—The data on superheated steam must be accepted conservatively in view of the uncertain value of the specific heat, which has formerly been taken as 0.48. Recent experiments have proven that for the pressures and superheats now in use this value is too low, and is, moreover, variable.

Columns 6 and 7 are based upon Greismann's investigations. Specific heat of superheated steam at constant pressure varies directly as the temperature, according to the law. Sp=0.0022 Ts--0.116.

and it is unfortunately a fact that, of the many experiments which have since been made by various authorities, none of them agree closely enough so that a definite value can be assigned to the specific heat of superheated steam for high pressures and high superheats. Nearly all investigators agree that the specific heat increases with the initial temperature, or in other words, with the pressure. They disagree as to whether the specific heat is constant for any given pressure and for different degrees of superheat. Late determinations by A. R. Dodge, indicate that at a given pressure it increases with the superheat. For present purposes we may consider the results of experiments by a German investigator, Greissmann, which show that the specific heat increases in direct proportion to the initial temperature. His results have been incorporated in Table VII and must be accepted conservatively in view of the foregoing explanation. With this in mind the increase in energy per pound of steam with the different degrees of superheat may be shown graphically. (See Fig. 4.) The arrows show that for 165 pounds steam pressure, absolute (150 pounds per sq. in. gauge), 324 B. t. u. are available in one pound of saturated steam expanding to a condenser pressure of about 28 inches of mercury, whereas 405 B. t. u. are available in one pound of the same steam superheated 100 degrees F.

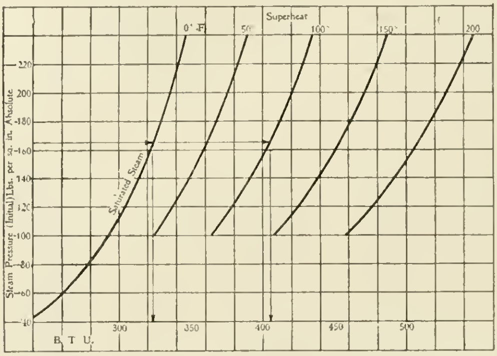

FIG. 4.—MAXIMUM WORK AVAILABLE PER POUND OF STEAM EXPANDING FROM GIVEN PRESSURE TO 100 DEGREES F.—28 INCHES VACUUM

These curves are based upon the steam expanding by the Rankine-Clausius cycle; an ideal cycle using adiabatic expansion with no compression, which practically applies to the modern steam turbine and piston engine alike.

TROUBLES

It must not be inferred from the good character of the results here presented that the use of high superheat is therefore to be universally recommended. The net saving in dollars at the coal pile is one thing; the ability of the plant attendants to cope with the problems arising in the use of superheat is another. For this reason the policy of recommending superheat universally is a poor one and should be modified by a full consideration of the following points:

The use of high temperature implies greater expansion of all metallic parts subjected to it. This, it is true, may be allowed for in the turbine by proper designing, and in the piping by great care and judgment in its arrangement, but it is also true that the difficulties in the control of superheat and the maintenance of uniform steam temperatures are greatly increased. The fireman must watch his fires much closer than before, and if he is at all negligent the superheat, even with a constant load, is liable to vary from 150 or 200 degrees F. to 0 or even to wet steam. Such extreme variations in temperature are sure to result sooner or later in creeping of piping, opening of joints and serious injury to engine or turbine.

At high temperatures more expensive pipe covering must be used or else heat losses increase rapidly. It is also found difficult to maintain tight joints and tight valves in the steam lines, due to high expansion. In one plant the first charge of superheat started every gasket in the main pipe line to leaking. These were of corrugated copper and had to be replaced.

In the design of several turbine plants, separators have been dispensed with, anticipating the use of superheat. Invariably at one time or another large quantities of moisture have found their way to the turbine, checking it nearly to a standstill. The fact that no permanent injury has apparently resulted has encouraged forgetfulness of the severe dynamic stresses which must have been exerted upon the turbine blading in order to suddenly absorb the enormous rotative inertia of the moving parts.

These are points which distinctly involve the so-called *personal elements* in power station design and operation. They cannot be expressed in dollars and cents, but are nevertheless of the utmost importance, as must be evident.

With intelligent operatives and proper means for controlling the superheat, beneficial results may be secured, but with ignorant and careless operatives and haphazard engineering the situation points to saturated steam simply from a standpoint of safety.

ENERGY TRANSFORMATIONS IN A STEAM BOILER—SUPERHEATER PLANT

The diagram, Fig. 5, has been prepared to show graphically the approximate distribution of work in the various parts of a steam boiler plant. Assuming all water at an initial temperature of 100 degrees F., the feed water heaters and economizers raise it to the temperature due to the pressure, viz.: 360 degrees for the case taken. If the feed heating equipment is not able to raise the water up to this temperature, the boiler is obliged to do so much more work. This preliminary part of the cycle requires 265 British thermal units. While the latent heat of the steam is being equalized 859 B. t. u. are put in by the boiler. Then if the superheater raises the total temperature to 500 degreess F. it further introduces* 84 B. t. u. into the steam, so that its total energy or thermal potential is 1208 B. t. u.

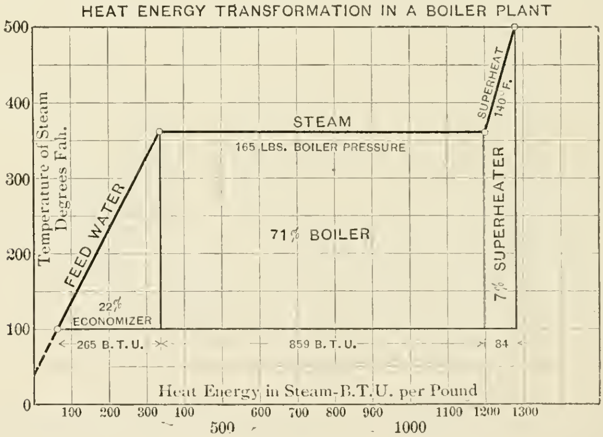

Fig. 5.

If all of the heat could be utilized by an engine or turbine, the steam consumption would be† $\frac{2545}{1208} = 2.1 +$ lbs. per horse power per hour. But for 165 pounds pressure and 140 degrees superheat only about 444 B. t. u. are available per pound for work, hence the steam consumption of an ideal engine is $\frac{2545}{444} = 5.75$ pounds per horse power. In the turbine test, Fig. 3, the actual water rate was about 11.5 pounds, hence the 400 kw turbine is just one-half $(\frac{5.75}{11.5})$ as efficient as the ideal engine. This, the writer believes, should be termed kinetic efficiency in distinction from mechanical or other forms of thermal efficiency. It measures the ability of an engine to turn available heat into *useful work*. The triple expansion Willans engine test, Fig. 1, shows a steam consumption of 11.8 pounds at 140 degrees superheat. Its kinetic efficiency is then $\frac{5.75}{11.8} = 48.5$ per cent. This, however, for an engine, is extremely high and the average engine falls far below it. On the other hand multiple stage turbines frequently show a higher efficiency than 55 per cent., sometimes 60 per cent., *with saturated steam*. The efficiency above given—50 per cent.—is therefore probably too low on account of the unavoidable error introduced in the use of an incorrect value for specific heat of superheated steam.

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*Assuming specific heat of superheated steam = 0.6.

†One B t. u. = 778 foot pounds
One hp = 33000 foot pounds per min.; } Therefore,

one hp = $\frac{33000 \times 60}{778}$ = 2545 B. t. u. expended per hour.

LINE CONSTRUCTION ON THE WARREN AND JAMESTOWN RAILROAD

THEODORE VARNEY

THE Warren and Jamestown Railway, which has recently begun operation, is of special interest owing to the fact that it is the first instance of a single-phase electric railway operated by gas engines as the prime movers. The current is generated in a power house without a boiler plant, transmitted at a potential of 22 000 volts over bare copper wires to transformer sub-

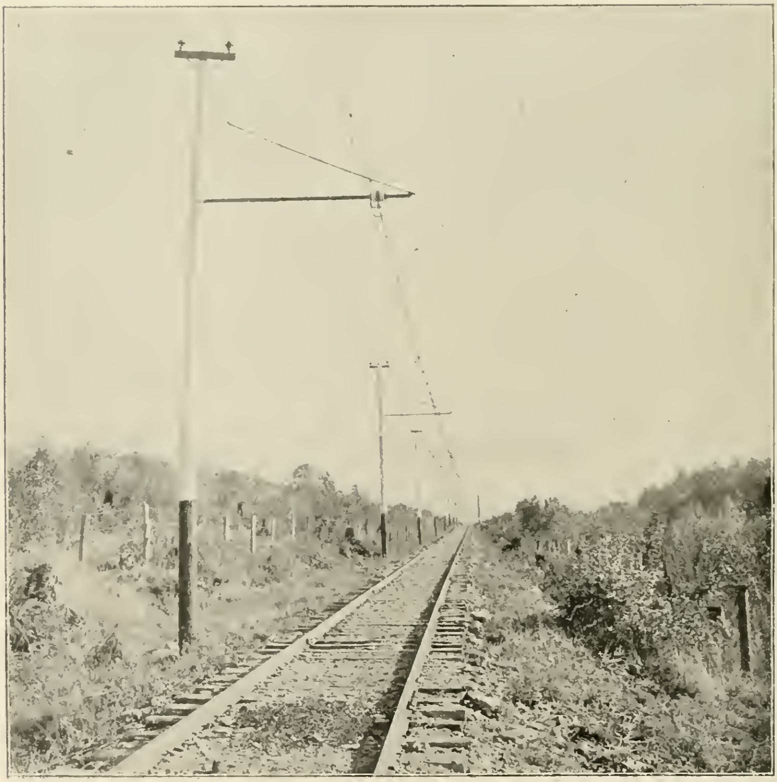

FIG. I—VIEW OF A SECTION OF THE WARREN & JAMESTOWN SINGLE-PHASE RAILWAY SHOWING THE CATENARY LINE CONSTRUCTION

stations without attendants and fed to the central trolley section at 3 300 volts and to the terminal section within the city limits at 550 volts.

The line is 26 miles long. There are two transformer substations containing transformers which lower the voltage from 22 000 volts to 3 300.

The city lines are fed from transformers mounted on poles along the track, which reduce the voltage from 3 300 to 550 volts.

The trolley line construction employed is the single catenary high tension system. The principal features in which this system differs from the usual low voltage equipment are the use of a steel supporting cable to relieve the copper trolley wire of undue strains, and the substitution of porcelain for moulded composition insulators.

By the use of a steel supporting cable the spans are made longer, and the number of points of support, and consequently the points of possible leakage, are reduced to a minimum.

Furthermore, the hammering of the trolley at the supporting ears, experienced in the old type of overhead suspension, is eliminated and the trolley wire becomes a smooth rigid line along which the collector shoe of the trolley slides without interruption.

By the use of a wide sliding contact shoe it is not necessary that the wire should be carefully aligned with the center of the track, in fact it is intentionally staggered slightly to distribute the wear on the shoe. This results in very simple curve construction since it is possible to run the trolley wire and catenary cable in straight lines between the poles thus forming chords instead of arcs of the curve. A chart is used in laying out the pole spacings on curves, and these spacings are adjusted to the curvature so that the maximum deviation of the chord from the center of the track is limited to eight and one-half inches on each side. The trolley shoe, in passing over the span, would therefore have the wire passed twice across seventeen inches of its surface.

This method is employed for all except the sharpest curves and the only additional material required besides that used on straight runs is a steady-strain for the trolley wire and a guy anchor for each pole.

The messenger cable is held at each bracket arm by a clamp and collar which embrace the porcelain so that the cable cannot come down even if the porcelain should break. The character of the insulation and the construction of the bracket arm are shown in Figs. 1 and 2.

The trolley line is of standard grooved section and is supported from the messenger cable by means of rigid hangers placed at ten foot intervals. These are adjusted in length so that the trolley wire is horizontal.

At necessary points throughout the line anchor clamps and strain ears are provided with guy cables running to porcelain strain insulators attached to the poles.

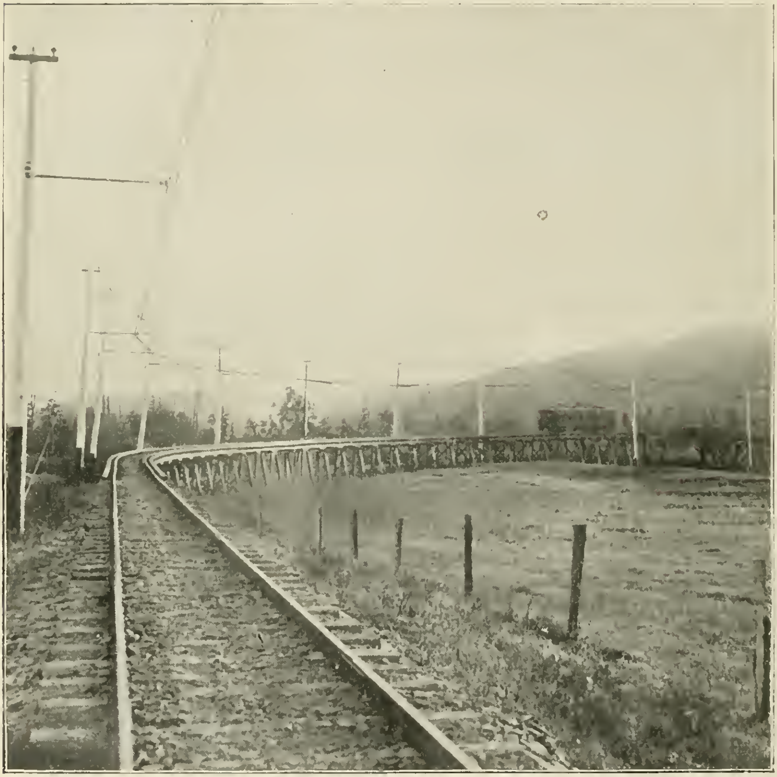

FIG. 2—VIEW OF A CURVE AND TRESTLE ON THE WARREN & JAMESTOWN SINGLE-PHASE RAILWAY, SHOWING CATENARY LINE CONSTRUCTION.

Section break insulators are provided in the trolley line at substations where a change in voltage occurs. These also afford means for cutting out a section without shutting off the entire line.

FUSES

CHARACTERISTICS—STANDARDIZATION—TYPES

DEAN HARVEY

CHARACTERISTICS

ONE of the principal features of the fuse is its overload time element. Before a given current will heat up the fuse metal to its melting temperature a certain fixed time must elapse. This time lag, as it is commonly called, rapidly decreases as the current increases. Fig. 1 shows the overload time element for a 400 ampere, 600 volt enclosed fuse. The fuse will carry a ten per cent overload indefinitely. It will open in about ten minutes at 600 amperes, in two minutes at 800 amperes, in one-half a minute at 1 000 amperes, or in about seven seconds at 2 000 amperes.

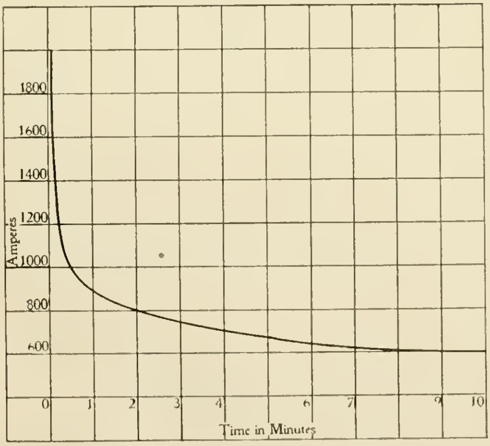

FIG. 1—CURVE SHOWING OVERLOAD CAPACITY OF 500-VOLT, 400-AMPERE NATIONAL STANDARD ENCLOSED FUSE

The time element lengthens with the increase of the capacity of the fuse. Fig. 2 shows the time required for standard enclosed fuses to operate at 50 per cent. overload, the time varying from 30 seconds for the 30 ampere fuse to ten minutes for the 600 ampere fuse. The large fuses, on account of their greater dimensions, require a much longer time to reach their maximum temperatures than fuses of small capacity. Fig. 3 shows a temperature curve for a 600 ampere, 250 volt enclosed fuse, the temperature being measured by a thermometer placed on the fuse at the center.

Enclosed fuses require considerable care both in design and manufacture to make them operate satisfactorily. The proportions and relative location of parts as well as the composition of fuses all have a marked effect on their operation when subjected either to overload or short-circuit. For this reason enclosed fuses should be returned to the factory to be refilled as otherwise their successful operation cannot be assured.

There is a common impression that fuses and overload circuit breakers have practically the same characteristics, though such is not the case. The overload circuit breaker depends for its operation upon the quantity of current, while the blowing of a fuse is dependent both upon the quantity of current, and upon the time during which it is applied. The circuit breaker will open immediately at any overload in excess of its setting, but will not operate at any smaller current, no matter how long continued. Standard fuses, on the other hand, will operate in time at as small an overload as twenty-five per cent., and will open in a proportionately shorter time with greater overloads.

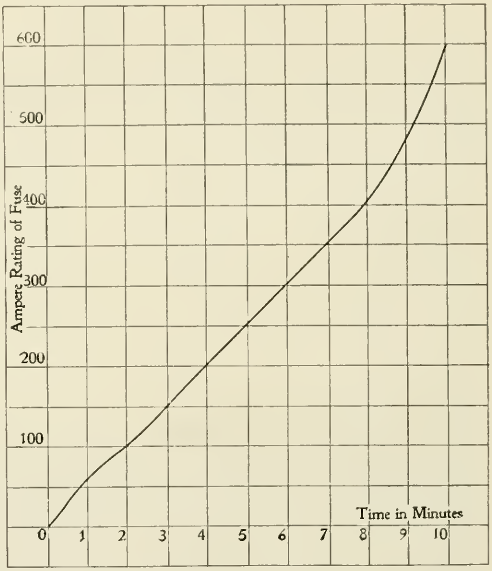

FIG. 2—CURVE SHOWING TIME REQUIRED FOR NATIONAL STANDARD ENCLOSED FUSES TO BLOW AT FIFTY PER CENT. OVERLOAD, FUSES COLD AT START

In determining the proper size of fuses to protect any apparatus, the overload time element should be considered in connection with the smallest current likely to prove dangerous. The low cost and the overload time element of the fuse render it particularly suitable for the protection of motor circuits, as it will carry a certain overload for a short time but will open if the overload continues.

For alternating-current motors taking a starting current much more than the full-load value, fuses which would carry the starting current would not give much protection except against a short-circuit. In order, therefore to afford adequate protection, a second set of fuses is necessary. These fuses should be switched into the circuit after the motor has come up to speed. When thus used they may be of suitable capacity to give much better protection to the motor.

The use of two enclosed fuses in parallel is not advisable unless sufficient resistance is placed directly in series with each fuse to render the contact resistance of the fuse negligible. Fuses have such low resistance that equal resistances in the two branches cannot be insured except by the arrangement just mentioned, as the resistance of the contacts would be proportionately large. When branches of unequal resistance are in parallel the two fuses do not carry equal currents and are likely to open the main circuit at a current less than their combined carrying capacity.

STANDARDIZATION

The various types of open link fuses which have been in common use for a number of years are objectionable as the fuse metal is exposed and there is a considerable flash and throwing of fuse metal when the fuse operates under heavy overload or short-circuit. This has made it necessary to enclose such fuses in cabinets except when installed in places where the flash and hot metal can do no harm. Also, open link fuses cannot be very accurately rated on account of the exposure of the fusible strip. It was to overcome these objections that the enclosed type of fuse was developed.

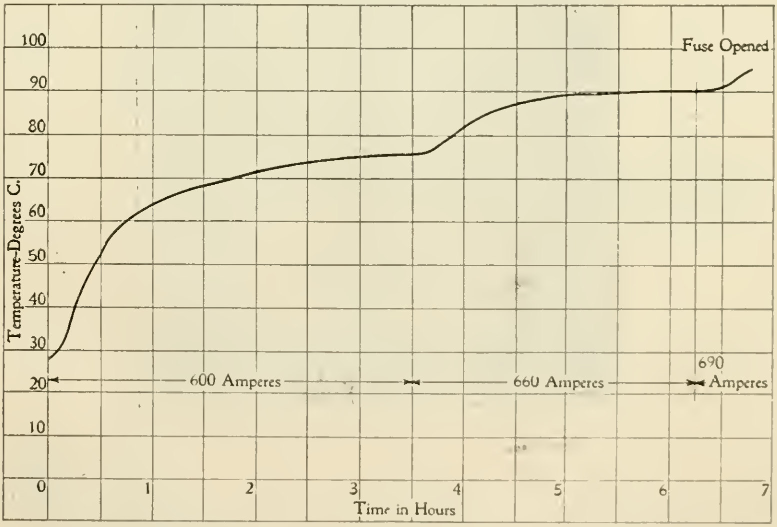

FIG. 3—CURVE SHOWING RATING TEST OF 250-VOLT, 600-AMPERE NATIONAL STANDARD ENCLOSED FUSE

The enclosed fuse consists essentially of a fusible element enclosed within a tube filled with a material to exclude the air and to facilitate the opening of the circuit when the fuse blows. Suitable terminals are provided so that the fuse may be mounted in a fuse block.

Complete lines of enclosed fuses were developed by several manufacturers, each make of fuse having different dimensions from those of other makes. This often made it very difficult to obtain fuses for renewals, as the corresponding capacities of the different makes did not have the same dimensions, and hence could not be used in the same fuse block. On this account dangerous substitutes for fuses were frequently used. Furthermore, enclosed fuses were not uniformly rated, as some makes were rated at about their maximum carrying capacity, while others were rated at about eighty per cent. of this amount, making a difference of twenty-five per cent. in the carrying capacity.

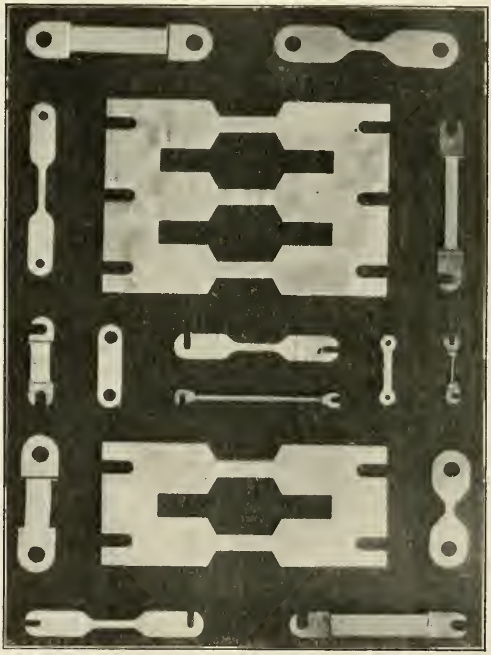

FIG. 4—LINE OF ALUMINUM AND COMPOSITION OPEN LINK FUSES

So much confusion resulted from the lack of uniformity of the commercial types of fuses that finally a conference was held between the representatives of the Underwriters National Electric Association and the fuse manufacturers, for the purpose of adopting standard requirements for enclosed fuses. A report of the preparation of the standard was given by Mr. H. O. Lacount in a recent paper.*

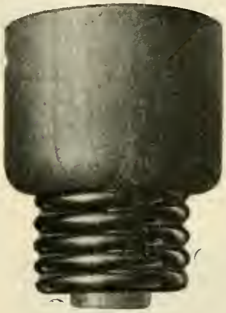

FIG. 5—PLUG FUSE CONTAINING REMOVABLE CARTRIDGE FUSE FOR 250 VOLTS, 1-60 AMPERES

Standard dimensions and test requirements were prepared for 250 and 600 volt fuses. These requirements are given in the 1905 edition of the National Electric Code under Rules 52 and 53. Fuses constructed in accordance with the standard are known as National Electrical Code Standard fuses. The dimensions of the fuses have been carefully worked out and are as small as it is safe to make them. Standard fuses are now made by all the principal fuse manufacturers, and are interchangeable in all National Electrical Code Standard fuse blocks of corresponding capacity. The use of fuses of special dimensions and particularly those smaller than the standard should be discouraged.

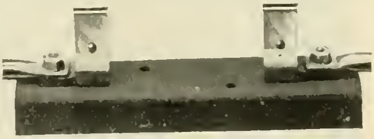

FIG. 6—NATIONAL STANDARD ENCLOSED FUSE BLOCK, FRONT CONNECTION, 250 VOLTS, 61-100 AMPERES

Much credit is due to the members of the Underwriters committee for their work in the preparation of the standard, and to the various fuse manufacturers, who gave their hearty co-operation.

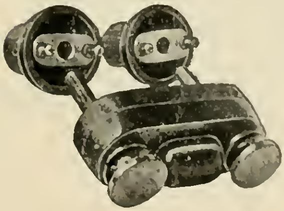

FIG. 7—EXPULSION TYPE FUSE BLOCK, 2 500 VOLTS, FOR SWITCHBOARD SERVICE

The standard divides enclosed fuses into classes according to the voltage and ampere capacity and specifies the dimensions for each class so that a given fuse can be used only in a fuse block of its class. The fuses are rated so that they will carry ten per cent. overload indefinitely, and will open at twenty-five per cent. overload. The following table gives the different classes and the maximum time within which enclosed fuses must operate at 50 per cent. overload.

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*See Trans. A. I. E. E., Sept. 1905.

Two classes according to voltage, (1) 0—250 volts.
(2) 251—600 volts.

Style of terminals	Ampere Rating	Time to operate
Cartridge fuse, ferrule contact	0—30	30 sec.
	31—60	1 min.
	61—100	2 min.
Cartridge fuse, knife-blade contact	101—200	4 min.
	201—400	8 min.
	401—600	10 min.

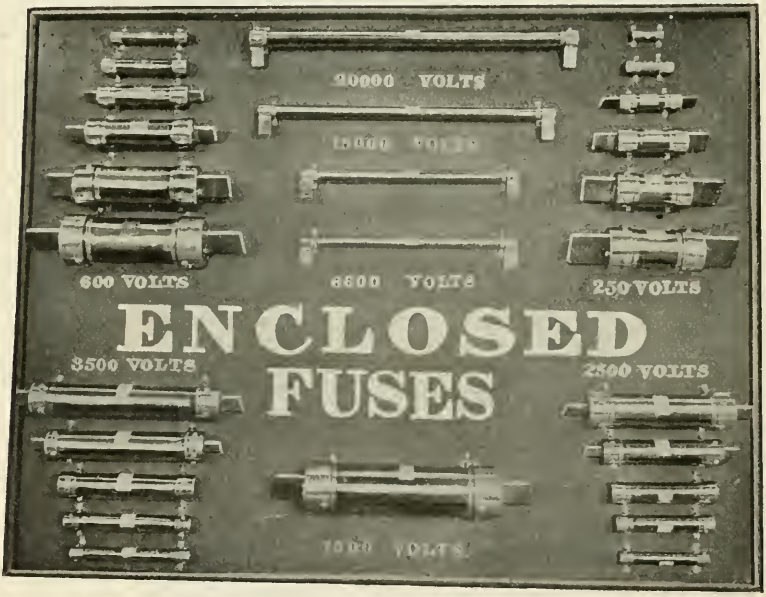

FIG. 8—LINE OF ENCLOSED FUSES

One fuse of each ampere classification is shown, as follows:

600 volts
0-30
31-60
61-100
101-200
201-400
401-600
3 500 volts
61-100
31-60
16-30
6-15
0-5

20 000 volts
0-5
15 000 volts
0-7
6 600 volts
0-4
5-15
1 500 volts
2 500-volt fuses used for 1 500-volt service up to 200 amperes.

250 volts
0-30
31-60
101-200
101-200
201-400
401-600
2 500 volts
61-100
31-60
16-31
6-15
0-5

The small 125 volt Edison plug fuses are used in capacities up to 30 amperes.

Fig. 5 shows the 250 volt Edison plug type of fuse used in capacities up to 60 amperes. Ordinary cartridge fuses are used within a fuse plug casing.

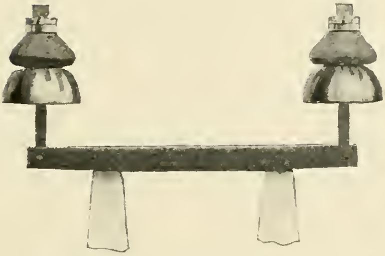

FIG. 9—HIGH POTENTIAL ENCLOSED FUSE BLOCK FOR 20 000-VOLT SERVICE

TYPES

A complete line of enclosed fuses (one fuse of each classification) is shown in Fig. 8. The same forms of terminals are used for all classes of fuses up to 3 500 volts inclusive, with ferrule contacts up to 60 amperes capacity, and knife-blade contacts for the larger fuses. Fuses for the higher potentials have terminals of a modified knife-blade type. This construction is especially desirable for high voltage fuses as it allows them to be handled by means of insulated fuse tongs, so that the attendant is not required to touch the fuse while it is in the fuse block.

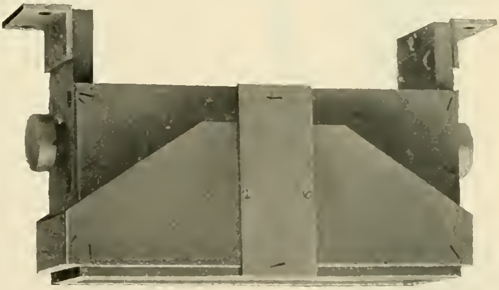

FIG. 10—RAILWAY FUSE BOX, 600 VOLTS

Fig. 6 shows a fuse block for a 250 volt 100 ampere enclosed fuse with knife-blade contacts. For the 1 500, 2 500 and 3 500 volt fuse blocks the fuse holders are mounted on marble bases. For higher voltages, porcelain insulators are used, mounted on metal bases. The fuse block shown in Fig. 9 is for 20 000 volt service.

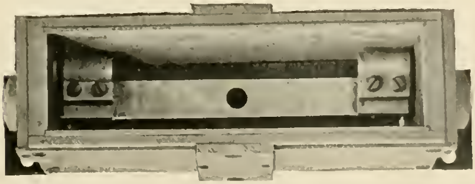

FIG. 11—RAILWAY TYPE FUSE BOX, SHOWING INTERIOR OF BOX AND RIBBON FUSE

The expulsion type fuse block shown in Fig. 7, is frequently used in switchboard work. This fuse block consists of a removable fuse holder of lignum vitae, equipped with terminals which fit into receptacles on the switchboard. The fuses are of the aluminum link type. Each half of the fuse holder has projections extending into corresponding depressions in the other half and fits closely over the fuse. The vent at the center of the fuse is small and the arc is blown out through the vent when the fuse opens. These fuse blocks are made in capacities up to 2 500 volts and 300 amperes.

The fuse block shown in Figs. 10 and 11 is used in electric railway work and is mounted underneath the car. The fuse consists of a copper ribbon with a hole at the center. The box is designed so as to provide a strong magnetic field to blow out the arc when the fuse opens.

For circuits of very high potential the demand for a cheap, reliable, circuit-opening device with overload time elements is met by the high potential fused circuit breaker. This device is made in various sizes up to 60 000 volts and 100 amperes capacity.

The fused circuit breaker shown in Fig. 12 is designed for potentials from 3 000 to 40 000 volts. The operating part of this apparatus consists of a movable wooden arm pivoted at one end to a stationary arm. When set the breaker is held closed by the fuse. When the fuse opens the movable arm is released and a spring forces it away from the stationary arm, thus making a very long break. The circuit breaker may also be operated by hand,

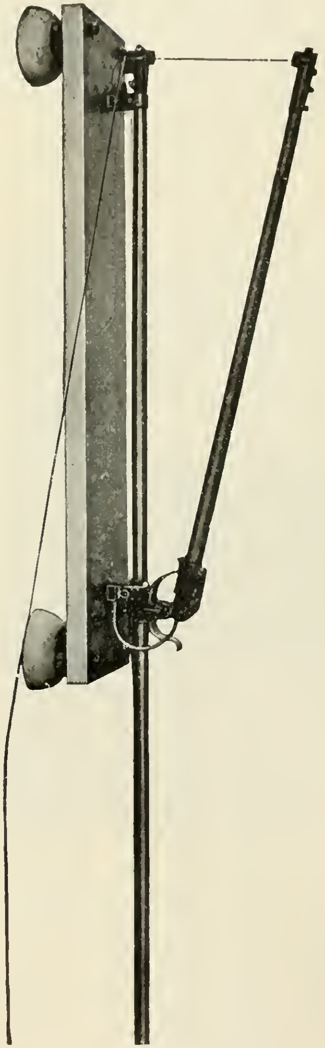

FIG. 12—HIGH POTENTIAL FUSED CIRCUIT-BREAKER, 3 000 TO 40 000 VOLTS, 100 AMPERES

PROTECTIVE APPARATUS

FOREIGN PRACTICE

Use of Resistance Methods of Installation - Cable Protection—Line Protection

N. J. NEALL

USE OF RESISTANCE

IN the preceding articles dealing with lightning arresters and choke coil practice abroad, casual reference only has been made to the use of resistances. Aside from the American arresters, which make a resistance as much a part of apparatus as any other, no such absolutely selective use is found in European practice.

Probably the one form most used, and thus particularly characteristic, is the form of water resistance, shown in Fig. 1. It consists essentially of a tube-like porcelain holder, containing water, connection being made at either end by an electrode passing through the cap and dipping into the water. A variation of this is shown in Fig. 2.

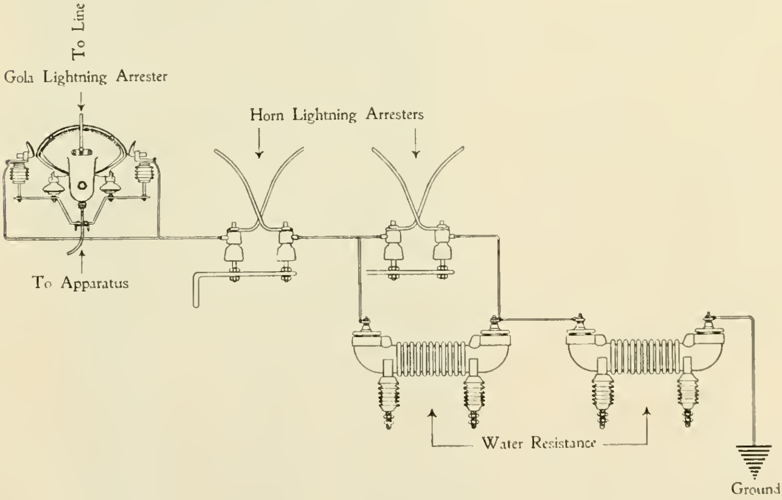

FIG. 1—ARRANGEMENT OF PROTECTIVE APPARATUS FOR 3 000 VOLT CIRCUIT AS PROPOSED BY GOLA.

Another form of water resistance is shown in Fig. 3, where the essential part consists of a glass tube holding the water. The tubes are connected by means of rubber hose to a large reservoir, which is grounded, connection to the lightning arrester proper being made at terminals at the top of the glass tubes.

All water resistances of pure water have several well known defects; they cannot carry much current, the water evaporates and the quality of the water must be kept very uniform to maintain equal service. They have, moreover, a high equivalent spark gap; that is, they do not discharge freely.

Another form of resistance is composed of wet clay in a porcelain tube, the clay being covered with oil to prevent evaporation of the moisture and thus it preserves a constant resistance. See Fig. 4. Resistance made of tubes of conducting and non-conducting particles are also used. See Fig. 5. One form of wire resistance is used. This consists of fine wire woven on an asbestos foundation. The coil thus formed is mounted on a frame and immersed in oil.

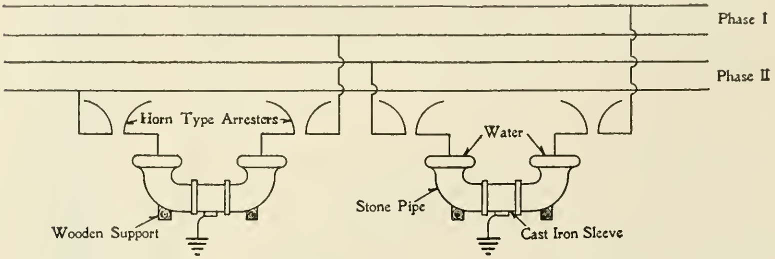

FIG. 2—HORN TYPE ARRESTERS WITH WATER RESISTANCES FOR USE ON A 5 000 VOLT TWO-PHASE LINE.

METHODS OF INSTALLATION

Torchio, in summarizing his recent observations in Italy, says in his A. I. E. E. paper at the October, 1905, meeting, that the best practice of to-day for the protection of Italian transmission lines indicates that the plan shown in Fig. 7 should be adopted. This plan shows:

"1st—The terminals of the transmission lines should be extended in a direct line some distance away from their entrance into the stations and the ends should be equipped with Siemens' horn arresters grounded through water resistances.

2nd—On the line side of the branch entering the station a water resistance static-discharger should be installed.

3rd—Choke coils and ordinary lightning arresters should be installed inside the stations. Possibly choke coils of the series lightning arrester type should also be used.

4th—Siemen's horn-arresters should be used on the poles along the line after careful study of the installation. Series lightning arresters with horn arresters, or ordinary lightning arresters may, however. be installed at particular points; as, for instance, where a line divides into branches, as at special points installed in a mountainous country."

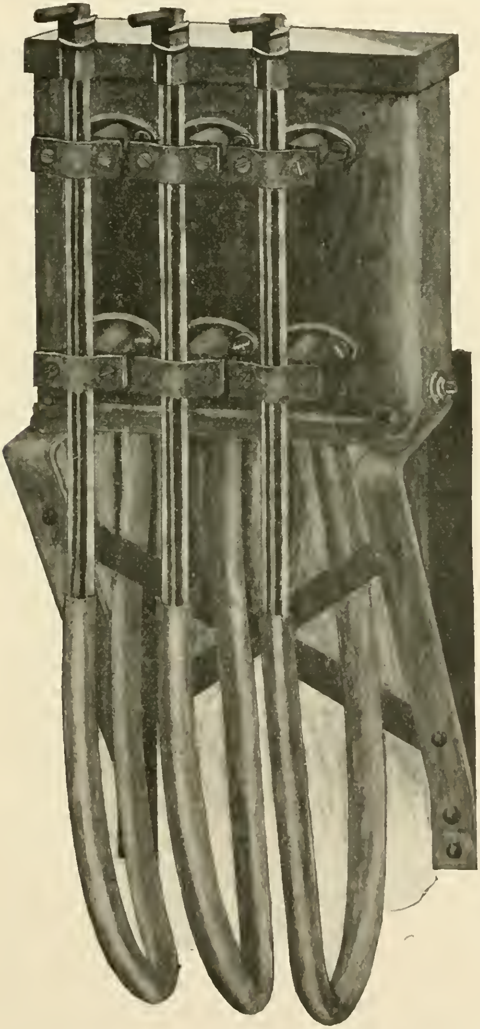

FIG. 3—A FORM OF WATER RESISTANCE USED IN GERMANY, AS MANUFACTURED BY THE ALLGEMEINE ELECTRICITATS GESELLSCHAFT.

In this connection P. H. Thomas says: "It is interesting that European engineers are advising the use of American lightning arresters, but it is also significant that they seem to find it wise to install special additional lightning protective apparatus. This would indicate that European engineers have not full confidence in American apparatus."

Typical foreign layouts of protective apparatus are shown in Figs. 1-2-6-7-8.

The peculiar points to be noted are:

1st—The use of more than one system of protection.

2nd—The use of arrester on either side of a choke coil.

3rd—The almost universal employment of the horn-arrester alone or in series with other gaps, etc.

4th—The frequent use of a water column, thereby occasioning a high operating loss.

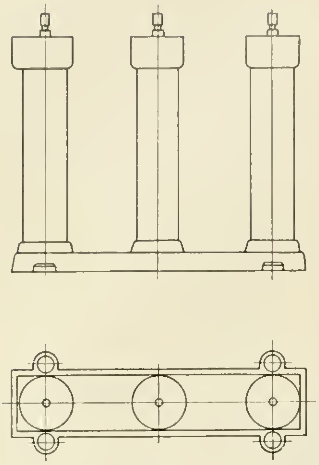

FIG. 4—FORM OF CLAY RESISTANCE USED ABROAD.

CABLE PROTECTION

The general conditions abroad have resulted in the development of many more high voltage cable systems than in America. In fact it is only recently that overhead high voltage transmission has been used to any extent. For this reason cable protection is with them an important and much studied matter.

In America this is far from being so important. In New York, for example, the Manhattan Elevated Railway Company has discarded all protective apparatus because of its giving rise to more trouble than it could prevent.

The question of protection for combined overhead transmission and high tension underground cables is an increasingly important one in America. Although certain methods have been proposed as well as experimentally investigated, their value is not yet absolutely determined.

Possibly the most notable work in cable protection has been carried out by the Land & Marine Cable Co. of Cologne-Nippes, several of whose methods of protection may be described as follows:

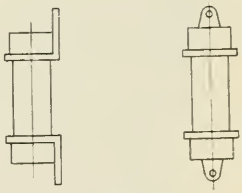

FIG. 5—FORM OF POWDER TUBE RESISTANCE USED ABROAD.

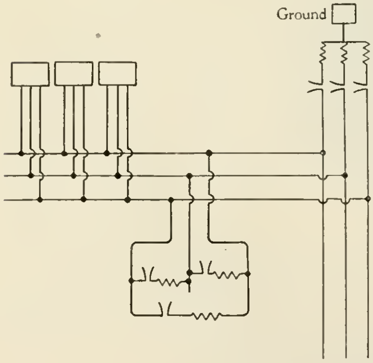

FIG. 6—A METHOD OF PROTECTION FOR HIGH VOLTAGE CIRCUITS.

The cable choke coil, used at the junction of overhead lines and cable, as may be seen from the illustration, Fig. 9, consists of a coil of a cable on a drum of suitable material. A weak point in the insulation near the line connection is supposed to offer the proper path to earth if a disturbance reaches the coil and the inductance of this arrangement facilitates the throwing back of the disturbance. Special insulation is provided between turns and the whole coil is insulated from earth.

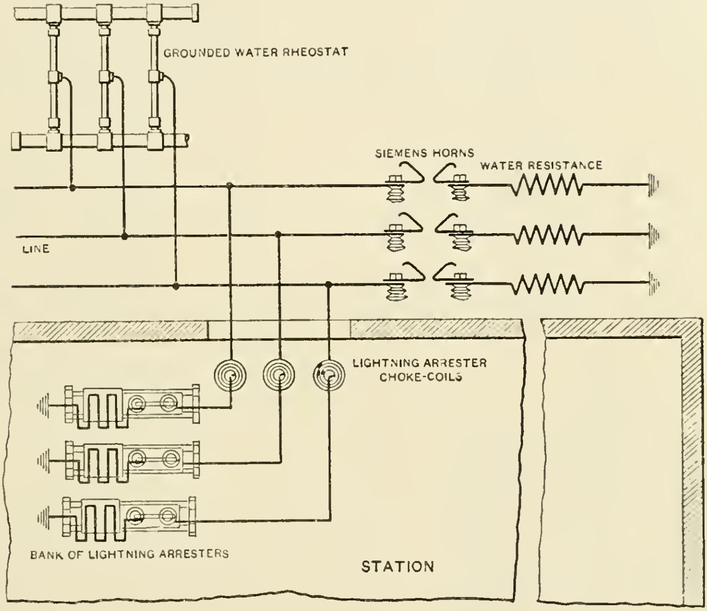

FIG. 7—SCHEME OF STATION PROTECTION BY TORCHIO.

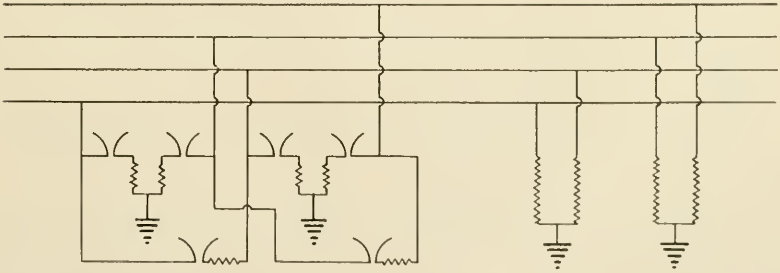

FIG. 8—DIAGRAM SHOWING PROTECTIVE APPARATUS USED FOR 5 000 VOLT GENEVA-CHEVRES TRANSMISSION.

Cables which are not connected to overhead lines, are nevertheless subject to static disturbances. These may arise from switching, from short-circuit, etc. For this purpose there is employed what is essentially an artificial weakening of the insulation at a known place or spot, and therefore any failure of the cable can be concentrated at these points. This arrangement is shown in Fig. 12, where we have a sort of spark gap consisting of two concentric electrodes *A* and *B*, which are separated from one another by a layer of insulation and an oil film *C*. *A* is connected to the conductor to be protected, *B* is connected to earth. *E* is a sort of comb arrangement of metal to prevent the breaking of the ground connection in case the lead sheath should be punctured by a bad short-circuit. The action of this device is as follows:

On the arrival of the static disturbance the layer of insulation is punctured and the oil pours in to smother the arc, so that the trouble is only of short duration. Fig. 13 shows the practical application of this method.

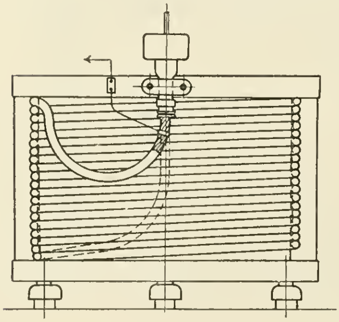

FIG. 9—CABLE CHOKE COIL IMMERSED IN OIL

Special tanks or receptacles are provided to contain these safety devices. In the ground lead of each fuse there is inserted a resistance to assist the oil in suppressing the arc. In order to learn at any time the exact locality of a break-down, signal wires are run from each tank to a bell and signal board. This is readily arranged to indicate the location of the trouble, which begins by the operation of the protective device, the current passing on this exciting a branch circuit, which in its turn operates the bell.

At the Oct. meeting of the A. I. E. E. in New York, Mr. H. W. Patchell, engineer in chief of The Charing Cross, West End and City Electricity Supply Company, Limited, of London, said, "the whole of our line is underground, sometimes three cables in one trough, sometimes two cables in a trough and at other times only one. When we started there were some surges. We tried to take care of the surging by the Siemens horn arresters, which we found were absolutely useless. When we worked with the small machines it was rather uncertain whether the arresters were useless or not, but when we worked with the 1 600 kw machines there was no question about it. The current caused by the surging made a bead on the horn arrester, which at once upset the calibration of it, so that at one moment we had a horn arrester set for 12 000 volts and the next moment, after a surge, we had one that was set below the pressure at which we were working. I think as far as spark-gap arresters are concerned, the less current we have, the less trouble we have. The arc forms a path for the current, of lower resistance than the initial path, and so causes an increased flow of current with a cumulative effect, so that the remedy may easily be worse than the disease. We went from the Siemens' horn arrester, with the aid of our contractors, Messrs. Lahmeyer, of Frankfort-on-Main, to a form of horn arrester which instead of finishing with a sharp point, as the Siemens' arrester did, has an almost parallel part at the lower end, which, of course, is closest at the bottom where the spark first jumps. The horns are enclosed with a glass cover in a small case, so that a chimney action ensues, which carries the arc rapidly up the parallel portion to the horns. One side of the lower portion of the

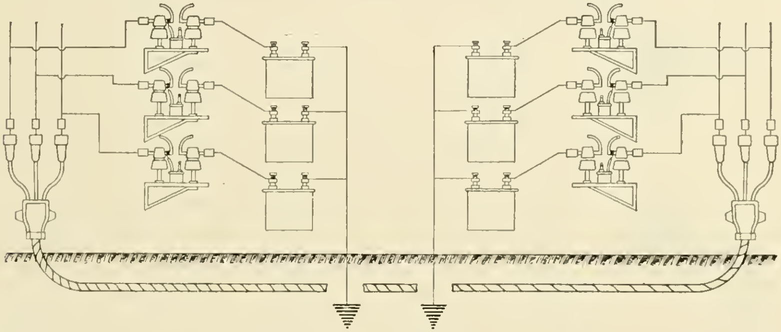

FIG. 10—AN INSTALLATION FOR THE PROTECTION OF A COMBINED OVERHEAD AND AND UNDERGROUND TRANSMISSION LINE, USING HORN LIGHTNING ARRESTERS AND SERIES RESISTANCES OF THE WIRE OIL-IMMERSED TYPE

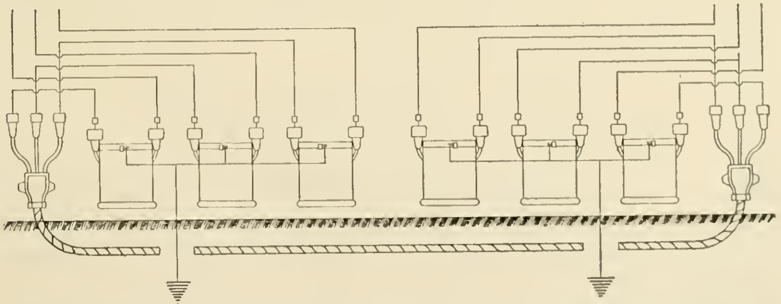

FIG. 11—AN INSTALLATION FOR THE PROTECTION OF A COMBINED OVERHEAD AND UNDERGROUND TRANSMISSION LINE, USING OIL-IMMERSED CHOKE COILS

horns is carbon, and we find in practice that while beads form between the horns, if both are copper, they keep quite clean if one is copper while the other is faced with carbon. We did work in connection with the arrester resistance. The resistances we tried were glycerine and water. We found that although they were quite right for some time after they were set up, some altered more than others. Th alterations puzzled us, but we at last traced it to some sodium from the air, which altered the resistance of the glycerine and water compound. We overcame that by putting a trace of sodium in the glycerine and water before starting off. We tried the cylinder type of resistance, but we found that we could not rely on them because the cylinder had to be turned around every time after a spark had passed, which had opened the gap, and for that reason we could not go much farther with them. The way we did was to put a very small transformer with practically no self-induction in the earth line. We had a spark gap, with a relay connected to an ordinary bell, and when the current passed through the spark gap the bell would ring. The station attendant then noted immediately the time and the number of the spark gap which had gone. These records were taken from our eight stations and assembled. In this way we are discovering some of the causes which result in the surges. We find particularly that most of the surges occur in the morning, when new machines are started up. We find if there has been a fog or a shock due to a surge, that the effect is almost the same as the shock to an individual. The surges go on for probably four or five hours. The main is nervous when it takes on current again. The surges mean nothing as far as continuity of operation goes, but after we have a short-circuit on the main, due to a faulty switch or a joint burning out, we find the pulsations go on, but do not give us any trouble and they gradually die away. They are

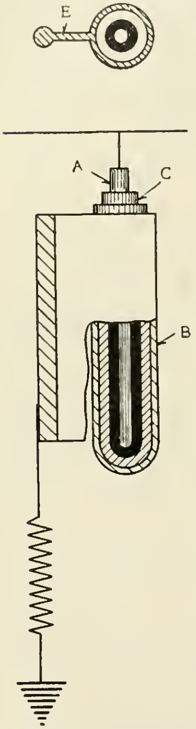

FIG. 12 — DIAGRAMMATIC REPRESENTATION OF THE DEVICE USED FOR ARTIFICIALLY WEAKENING THE CABLE INSULATION.

curious effects, to which I would be glad if some of the physicists would turn their attention to."

In America only one device has been prepared for the purpose of cable protection against disturbances arising within itself, the so called static discharger. This consists of a number of units of multigaps and carbon pencils in series across the legs of a line, there being nothing essentially novel in the arrangement other than its application. See Fig. 14.

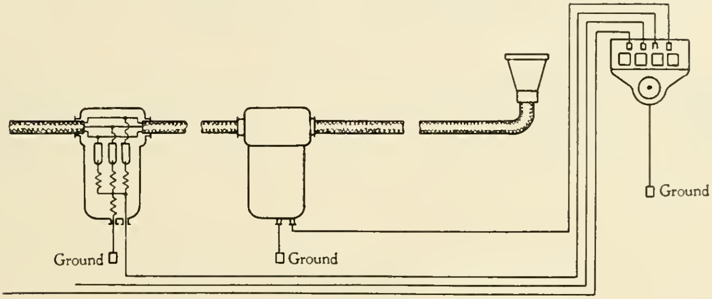

FIG. 13—A METHOD OF EMPLOYING THE WEAK SPOT INSULATION SCHEME, TOGETHER WITH INDICATORS TO SHOW THE POINT OF BREAKDOWN.

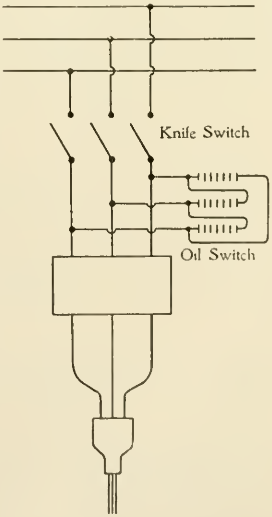

FIG. 14—A DIAGRAMMATIC REPRESENTATION OF CABLE PROTECTION BY THE USE OF MULTIGAPS AND CARBON PENCILS IN SERIES ACROSS A THREE-PHASE LINE.

The arrester arrangement known as low equivalent has been tried abroad with success. The experience in America has been too limited to permit of any close information as to its real merits.

LINE PROTECTION

The development of power transmission in Europe does not seem to have brought with it the attention to protection against direct strokes which has so greatly interested American engineers during the last six years. The employment of iron towers has doubtless been of benefit. The literature of the past decade gives no information of moment on this score, and one is led to conclude that such trouble is either very much less in Europe than here, or that the overhead plants so far constructed have not been particularly exposed.

PHANTOM GROUNDS

S. M. KINTNER

THE ringing of a magneto when connected to a condenser has been the cause of a great deal of annoyance and mystery among some electrical workers. Much time has been spent in hunting for grounds which a misinterpretation of the magneto test indicated were present on a system of considerable capacity to ground. This action of a magneto is now quite well understood. The same phenomenon when observed as in the following instance is not so generally recognized.

The armatures of alternators are sometimes reported grounded because the alternating-current voltmeter connected from one terminal to ground indicates voltage when the machine is running. An instance of this kind came to notice recently in which a medium sized three-phase star-connected alternator was reported grounded in the armature. In reporting the trouble the observer gave the following data and results of tests made to determine the certainty of the ground and its location.

The normal voltage between terminals was 2 300 and the frequency 60 cycles per second.

The voltage from each of the three terminals to ground, measured by a voltmeter on the secondary of a transformer, one primary terminal of which is connected to ground while the other was connected successively to each of the alternator terminals while the alternator was running, was as follows:

When using a voltmeter transformer, 1 400 volts.
" " " 1 kw shunt " 860 "
" " " 5 " " " 0 "
" " " voltmeter and series resistance, 980 volts.

Readings were also reported on the alternating-current voltmeter from each conductor on the armature, to ground. These last readings were perfectly symmetrical for each phase, the values shading, in each case, from a maximum at the end of each phase to zero at the common connection or neutral.

The reading on a direct-current voltmeter placed in series with a 130 volt direct-current machine and the insulation was zero. The voltmeter resistance, 11 000 ohms.

The direct-current meter, which could doubtless be read to one-fourth of each division, indicated by its failure to show a deflection that the insulation resistance was not less than 5.7 megohms and probably more, as the deflection was reported as zero.

The readings of the alternating-current instruments may be understood by referring to the diagrams, Figs. 1 and 2. In Fig. 1 the star winding is shown diagrammatically, each phase ending at the points, *A*, *B* and *C*, respectively. The distributed capacity of the windings to iron is represented by the small condensers. The transformer and voltmeter are shown diagrammatically on the right. Fig. 2 shows the voltmeter transformer connected to one terminal and the rest of the circuit is shown as consisting of a generated voltage in one phase of the machine (plus a certain voltage derived as a resultant of the other two) and capacity to the ground of the other windings, to the ground and back to the transformer. The indication on the voltmeter depends upon the voltage impressed upon the high tension side of the transformer. The voltage that is thus impressed is dependent upon the current

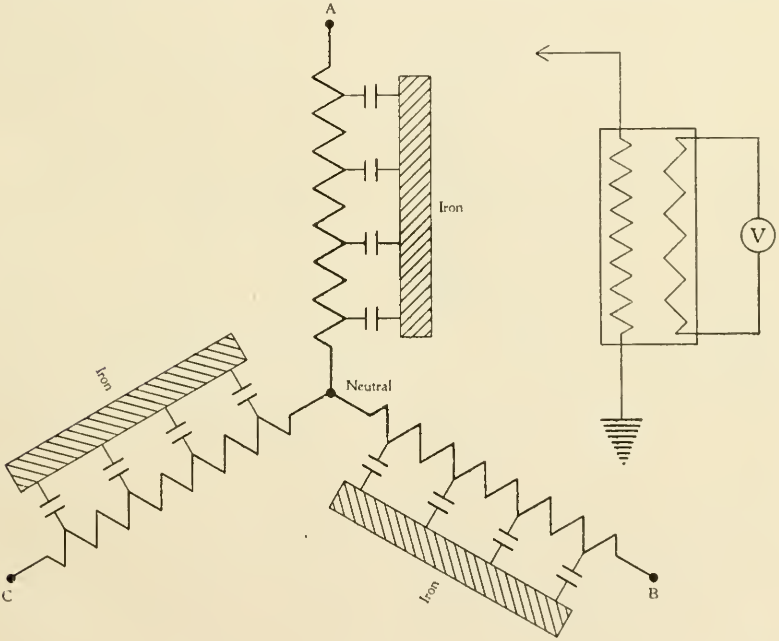

FIG. 1

flowing, as with a larger current flowing a greater percentage of the generated voltage will be required to force this current through the capacity. This accounts for the variation of the readings with the sizes of transformers as the requirements of magnetising and iron loss currents varied considerably for the different sizes of transformers used. In the data here given this condition exists: The smaller the transformer, the larger the voltage reported. The current requirements of the five kw transformer were so great that no readable indication was produced on the voltmeter, as most of the voltage drop was across the condenser effect. The data submitted had been very carefully obtained and was in most consistent agreement in proving the excellence of the insulation, not the lack of it.

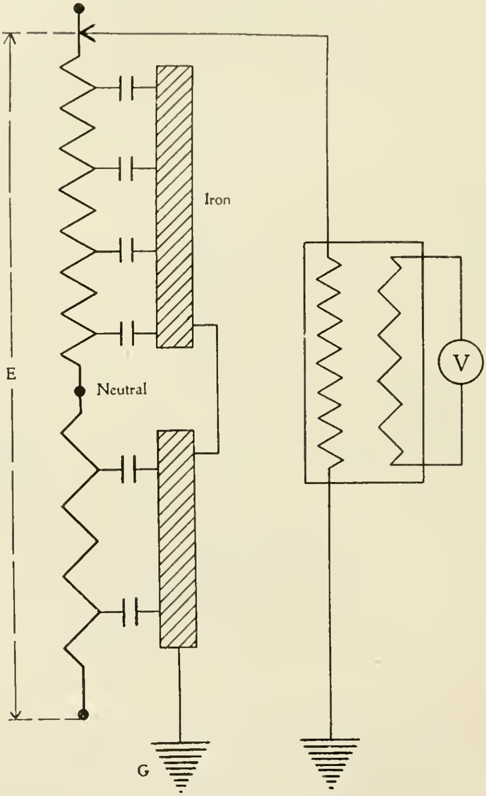

FIG. 2

EXPERIENCE ON THE ROAD

SOME OF THE PRACTICAL EXPERIENCES OF A DISTRICT OFFICE ENGINEER

C. L. ABBOTT

LARGE STARTING CURRENT

On several occasions men who have been sent out to investigate troubles with direct-current motor starting rheostats, have discovered a large momentary current in starting. In a recent case a 30 hp, 110 volt motor drew 400 amperes from the line. This was the result of a weak field due to wrong connections as shown in Fig. 1. The correct method is shown in Fig. 2.

BAD COMMUTATION

A large generator would not commutate well on heavy loads. It was found that the machine was guaranteed to over-compound from 550 to 600 volts, at 100 r. p. m., but on account of having to work in with other machines on a large system, it could not be operated above 550 volts as a maximum. This caused the machine to work low on the saturation curve, and slight sparking at some points with a constantly shifting load. As the engine was relatively large compared with the generator, it was decided to lower the speed to 90 r. p. m., and work the field more nearly as designed. This change made the generator satisfactory to the local company.

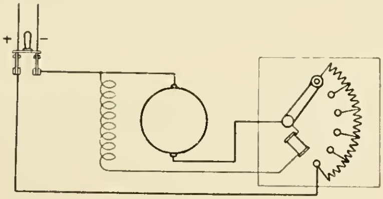

FIG. 1

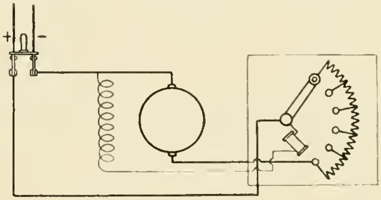

FIG. 2

A NEW USE FOR MICA

A rotating field alternator hummed badly and investigation showed that the finger plates on the stationary armature were not stiff enough to hold the outer laminations firm between the coil slots. Several efforts were made to stop the trouble by upsetting the iron and finger plates, without entirely stopping the trouble. Finally thin strips of mica were driven between the iron laminae, after having been coated with shellac. This method was successful.

PARALLEL RUNNING OF ALTERNATORS

Two belted alternators had never been successfully operated in parallel although driven from the same shaft, and with pulleys of apparently the same diameters. A steel tape was run over each of the driving pulleys, and a difference in circumference of more than an inch was found. As the driving pulley could not readily be turned, one of the driven pulleys was taken off and turned down to give the desired speed.

PARALLEL RUNNING OF TRANSFORMERS

A lot of transformers connected in delta and in a system with a large amount of other apparatus was found to be running too hot. Tests were made of efficiency, iron loss, regulation, cross currents, power-factor, etc. Then some one discovered that the oil was low. When the oil was brought up to its proper level, the temperature went down to where it belonged.

BAD COMPOUNDING

A complaint was made that a compound-wound direct-current generator in service more than a year, did not compound properly, and the switchboard attendant had frequently to adjust the voltage. Investigation showed that the load had been put between the negative and the equalizer, cutting out the series coil. When the matter was explained, the local electrician said he felt like an old man, who, after forty years discovered that the clock he had wound daily was of the eight day variety.

THE
ELECTRIC JOURNAL

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Gas Power

The article on the Warren Gas Power Plant which appears in this issue of the JOURNAL invites attention to a recent conspicuous engineering development. Convinced as we have been of the potential possibilities of the combustion engine in power generation, we have nevertheless not fully recognized the extent of what has been achieved. Comparatively small engines, of course, have been successfully used in great number, and their performance, in sizes up to about 300 horse power, has been fairly comparable with that of steam driven units. Engineers, however, have been prone to make indefinite prediction for the successful development of the gas engine in unlimited size and capable of meeting the requirements of modern power plant service.

The success of the engines at Warren, therefore, is especially significant, for we now see what the large gas engine will do. The engines in question, while of but 500 horse power each, are precisely the same in design as the larger engines, and relatively therefore they afford the same evidence that would be obtained in Corliss steam engine practice from an engine of that size.

The combustion engine is certain to find henceforth very extended use. Already some ten or twelve units of from 3 000 to 4 000 horse power have been contracted for, besides a large number of medium sized ones, and the prediction might be justified that another twelve months will see the gas engine well established as the preferable type of prime mover where gas fuel is available in adequate quantity and at a sufficiently low cost. This development will naturally initiate with industrial plants now using by-product gas under steam boilers or allowing it to go to waste, and in the natural gas fields where there are many natural centers of power distribution. We may venture to expect that its subsequent economic utility will become quite general. The gas producer, crude and simple as it might be comparatively termed, but hitherto lacking energetic development, will, with the field that now lies before it, receive the attention it deserves. Many industrial plants now generating and distributing power with great waste will be able to effect almost incredible saving by the use of a central plant supplying gas to engines for power and to various processes for fuel purposes; and all with comparatively no loss in transmission.

Altogether, when we recognize that this thermally most efficient type of prime mover has reached the mark mechanically; when we contemplate the amount of power-producing gas which now goes to waste or is at present inefficiently used; furthermore, that gas may be made, transmitted and used with a markedly better net efficiency than now attends the use of steam; and when we finally realize what a broad field for investigation and knowledge this subject presents, the conclusion is evident that our engineers will henceforth be required to devote much thought to the problems involved.

E. H. Sniffin

The Electro-Chemical Industry

Electricity is pre-eminent by reason of the new methods it has introduced. New methods in turn give rise not only to more efficient means of securing results formerly obtained by other methods, but also give rise to results absolutely unattainable by other means. Carborundum is one of the resultant products made possible by the introduction of electricity. The article by Mr. H. R. Stuart in this issue of the Journal describes some of the apparatus used in the production of carborundum by the electric furnace. The process of making carborundum is an excellent example of one of the new methods that the use of electricity has introduced. The electric furnace gives us the ability to obtain temperatures far beyond those obtainable by any other known means. The temperature attainable within an electric furnace is simply a question of putting in heat on the one hand and its radiation on the other. Within certain limits this ratio, and hence the temperature, may be made anything desired.

There are many other products of this new electric method. Graphite, calcium carbide and phosphorus are among those that are well known owing to the extent to which the electric furnace process has been used in their production. This method, however, is one whose usefulness is only just beginning to be properly appreciated, and the electric furnace of the future is undoubtedly destined to become an industrial factor of great productiveness.

Another new manufacturing method is that covered by the general term, "electrolytic action." The electrolytic refining of copper and other metals is an item that comes under this head. The aluminum industry owes its existence to this property of electricity.

Another source of industrial activity founded on this property is the ability of electricity to break up chemical compounds into their elements. These elements may then be reunited in any manner desired. Common salt is thus electrolytically broken up into chlorine and sodium. The chlorine is absorbed by lime to make bleaching powder, and the sodium unites with water to make sodium hydrate or caustic soda. This latter is again decomposed electrolytically to form metallic sodium, which is again recombined into almost numberless useful substances. Still another product of the electrolytic decomposition of salt is chlorate of sodium, which in turn finds its way into matches, explosives and numerous other products. Salt is only one of many of the compounds that can be successfully dissociated and recombined. The method is applicable to practically any compound that enters into a conducting solution.

Electricity makes for new and improved methods, and such methods make not only for higher efficiency, but also for results not obtainable by other agents. PAUL M. LINCOLN

Twenty-five Cycle Lighting

The relation of frequency to illumination of incandescent lamps has been the subject of discussion among engineers on many occasions. Very often these discussions deal with only a part of the subject and do not take into consideration other elements which enter into the problem.

The fundamental physical condition is that the heat generated by the current passing through the filament is not continuous but varies through the cycle approximately in proportion to the square of the instantaneous value of the current. This variation in the production of heat causes a variation in the temperature of the filament. The variation in temperature is in turn dependent upon the specific heat of the filament, upon its mass and upon the rate at which heat is dissipated. The variation in temperature causes a variation in the luminous intensity or the candle-power of the lamp. The foregoing conditions are subject to variation in different cases. In the first place, the variation in the current is not always at the same rate; one condition prevails when the current wave is of the sine form and another when the wave is flatter than the sine wave, or when it is more pointed. The generation of heat varies from zero to maximum. If successive intervals of equal duration be taken, such that alternate intervals contain the maximum and the intervening the minimum rate of heat production in the filament, then the total heat in one of these intervals is about four times that in the other interval, in the case of the sine wave. If the wave be flatter than a sine wave the relative values of current and of heating during the maximum interval are decreased and those in the minimum interval are increased, thereby reducing the range of fluctuation in temperature. Conversely, if the wave be more pointed than the sine wave, the fluctuations are increased. It follows, therefore, that the heat produced in the filament in successive intervals is very intimately dependent upon the wave form, especially as the rate at which heat is produced does not vary directly as the current but as the square of the current, and that the variations are less the flatter the wave.

There may be other variations in current besides those occasioned by the normal action of alternating current. Thus, if two alternators running in parallel do not have uniform and equal rotative speeds there may be a periodical fluctuation at a lower frequency than the normal frequency of the circuit, which manifests itself in the motion of sensitive indicating instruments on the switchboard and which will likewise tend to produce somewhat similar effects in incandescent lamps.

The changes in temperature and in illumination, caused by the variations in the heat developed in the filament, are obviously dependent upon the diameter and other characteristics of the carbon filament; or, expressing the same thing in another way, upon the voltage, the candle-power and the efficiency of the lamp, as these elements are factors upon which the diameter and other characteristics of the filament depend. The final result is a variation in candle-power, for which curves corresponding to certain conditions are given in an article in this issue of the JOURNAL.

The further question is the effect of this variation in candle-power upon the eye. The problem is both physical and physiological. New elements enter; the intensity of illumination; the character of surrounding surfaces, such as reflecting walls and the like; the purposes for which the illumination is used, all enter as factors. Moreover, the stability of the filament is a feature of some consequence as a rapidly vibrating filament, which may under certain conditions result from the reaction of the current in the filament upon an external magnetic field, may produce a noticeable effect upon the eye. The eye is apparently more sensitive to the rapid variations in illumination when the light is reflected from a surface, such as a white wall, than it is when it comes directly from the filament of the lamp. Different portions of the retina are not equally sensitive, light impinging upon the eye at an angle of about 45 degrees seems to strike a more sensitive region than light which comes from directly in front of the eye.

In considering the effect upon the eye it is necessary to consider not only those vibrations which may be readily observed or detected when they are looked for, but also to note whether the fluctuation produces fatigue or nervousness, as the result of continuous use of the light in office work, although there may be no apparent immediate inconvenience. I recall that the eminent physicist, the late Professor Rowland, remarked that the proper test for the operation of incandescent lamps on low frequency alternating current would be to have an old lady use the light for reading and see whether it hurt her eyes. On second thought, this suggestion that the problem is really a physiological one does not seem to be far wrong.

The problem is certainly a very interesting one from the theoretical standpoint. The real test, however, is the practical one of actual experience. Twenty-five cycle current is in pretty general use for incandescent lighting. The report in this issue of the illumination of the city of Buffalo is quite to the point. My own view of the matter is to the effect that the illumination by incandescent lamps at 25 cycles is, in general, quite satisfactory for most purposes, but it is impossible to give a broad assurance that it will always be found satisfactory for the reason that differences in the character of the current supplied and of the lamps used are important factors, and, moreover, lamps that would be satisfactory under most surroundings and for many kinds of service might be unsatisfactory in other surroundings when the requirements were quite exacting.

CHAS. F. SCOTT

A Spelling Lesson

I have noticed articles from time to time on Engineering English and have heard college professors and others speak of the importance of acquiring facility in the use of English. Such things, however, are apt to make only a general impression. A much more distinct and definite impression was made in a report which I had occasion to examine a short time ago. In it occurred various specimens of distorted aggregations of letters, of which the following are examples: togeather, stile, acceliration, spesific, iner, ohmes, fragel, extry, indipendently, catridge, bilt, arester, coeficant, usaly, and trolly.

I was especially struck by the nature of the impression which these errors made upon me. They had a tendency to discredit the intelligence of the writer and to give a suspicion that carelessness and inaccuracy might characterize his ideas and his statements as well as his orthography. The report as a whole had evidently involved a great deal of painstaking work; hence, it was a pity to have the excellence of the impression which it should have made marred by errors seemingly trivial but inexcusable. General reform in spelling may be a very commendable movement, but it is rather dangerous to be a pioneer in such matters.

When I was called upon to contribute something to the Journal it seemed to me that what has just been related was of sufficient interest and consequence to be worth a passing note. I have in mind that people who live in glass houses should not throw stones; so as a precaution for my personal safety I will not sign my name.

Co-operative Electrical Development

The publicity plans of the Co-operative Electrical Development Association deserve the hearty support of the several hundred thousand men directly and indirectly interested in the extension of electric service. As Mr. J. Robert Crouse, Jr., has insistently pointed out, the result must be obtained by co-operation. Now that the plans for working out this co-operation in a large way are in the hands of a representative committee, it looks as if we were to have aggressive action. In our opinion, however, the more rapid extension of electric service in any particular community will remain largely a special problem, and an aid bureau of experts might be useful in looking into individual cases of slow or arrested electrical development.

J. H. Smith

THE NEW HAVEN AND THE SARNIA TUNNEL ELECTRIFICATIONS

B. G. LAMME

Chief Engineer, Westinghouse Electric & Mfg. Company

Mr. Lamme, who is the recognized leader in single-phase railway development, presented a paper before the New York Railroad Club, March 16th, on "Alternating-Current Electric Systems for Heavy Railway Service." The paper gives a comprehensive review of the development of direct-current traction, the limitations of low voltage in distance of transmission and amount of power which can be taken from a trolley wire, the development of the rotary converter sub-station and the third rail; high tension alternating current on the trolley, first by the portable sub-station which converts from alternating to direct-current, which is supplied to direct-current motors; second, by the polyphase system with induction motors; third, by the Arnold electro-pneumatic system; fourth by the single-phase system.

The part of the paper describing the single-phase system and the equipments now under construction for the New York, New Haven and Hartford Railroad and for the Grand Trunk Railway, is reproduced.—Ed.

THE SINGLE-PHASE SYSTEM

The single-phase system contains the following features:

1. Alternating current is used on account of its facilities for transformation.

2. One trolley wire only is used, by adopting single-phase alternating current.

3. With alternating current and one trolley wire only, any desirable voltage can be used on the trolley line.

4. By using alternating current an efficient means for varying the voltage to the motors is obtained. With single-phase there is only one supply circuit to be handled, and the variable voltage apparatus can be given the simplest and most efficient form.

5. A type of motor was developed which can have its speed varied by varying the voltage supplied to it, and which uses power practically in proportion to the load, when operated in connection with the above variable voltage supply circuit.

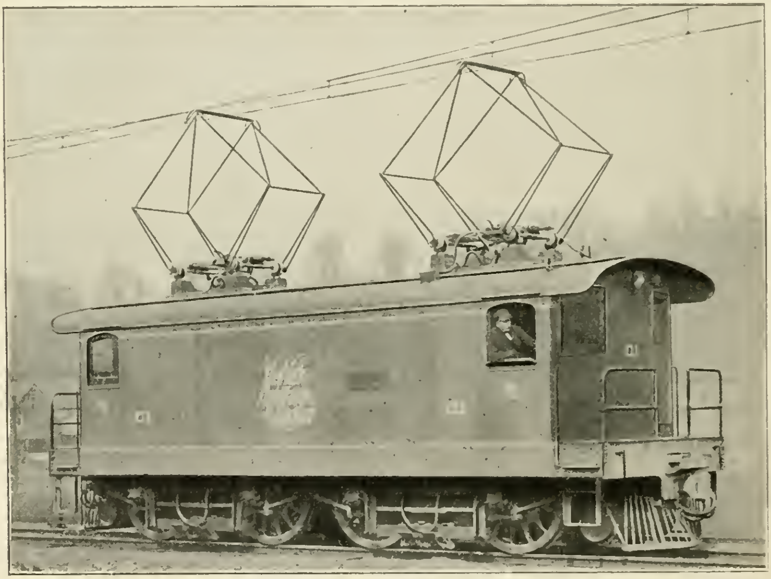
6. The motor is preferably wound for low voltage and the same transformer which is used for stepping down from the trolley voltage to the motor voltage can also be used for obtaining the

desired voltage variation, for varying the speed, and the power in proportion to the speed.

7. The motor is inherently of a variable speed type and can automatically adjust its speed to that of other motors driving the same load, with but very small unbalancing of the loads on the individual motors.

8. The type of motor developed is one which can be used on direct current also.

The above covers the principal features of what is now known as the single-phase railway system. It is intended to cover practically all the best features of other systems. It is, in fact, a tool especially designed to do a particular piece of work and is not primarily an adaptation of existing apparatus to a new condition. The single-phase system may be described briefly as follows:



FIRST NEW HAVEN LOCOMOTIVE, ON INTERWORKS RAILWAY AT EAST PITTSBURG

Single-phase alternating current is fed either directly from the power house into the trolley line, or from a high voltage transmission circuit by step-down transformers, into the trolley system. A high voltage trolley current is carried into the car or locomotive and is stepped down to a suitable voltage to be applied directly to the motors themselves. At the same time the step-down transformer is provided with variable voltage connections whereby the voltage supplied to the motor can be varied up or down over any desired range. The type of motor used is one in which the speed varies directly as the voltage applied to it is varied. Speed control is thus obtained without wasting energy other than that in the motor itself. It therefore permits efficient speed control over any range desired by simply varying the voltage over the necessary range. There is but one transformation of energy between the high voltage trolley wire and the motors which is that of the step-down transformer, and as stated before, the alternating voltage transformer is our most efficient device for transforming energy. At the same time this transformer serves the double purpose of transformation and regulation, as mentioned above.

This method of varying the speed by varying the voltage supplied to the motor is not limited to this particular type of motor, for the ordinary direct-current railway motor can have its speed varied in the same manner. However, with direct current, no simple means has yet been devised for varying the voltage efficiently.

The control of the speed and power by varying the voltage may be roughly compared with the control of a steam locomotive by varying the steam pressure. Throttling varies the pressure applied at the cylinders and thus varies the speed and power. However, the equivalent of the variable cut-off is not found in the motor, but it may be said that voltage control in the motor is the equivalent of combined throttling and variable cut-off in the steam engine.

There are several variations in the types of single-phase motors used by the different manufacturers, but the principal features of the system are common to all. In its characteristics of variable speed over any desired range, and consumption of power in proportion to the load, the single-phase equipment is on much the same footing as the steam locomotive, as just indicated above. The equipment also possesses the ability to operate at increased speed by increasing the voltage above the normal and can thus make up for lost time, when desired.

It is important that under certain conditions an electric locomotive should be able to act as a brake, or to return energy to the line, as when taking loads down grade, for instance. There is but one way in which the car equipment can act as a brake; namely, by reversing the function of the motors and converting them into generators of power, the driving power being furnished by the train in movement. In acting as generators there are two ways in which an electric equipment can expend its power: First, by wasting it in resistance as heat, and second, by feeding it back into the line in case there is any other load on the line which can absorb the power.

The motors of the single-phase system can readily meet the first of these conditions; namely, that of feeding power into a resistance. As the motors are of the commutator type, and are, in reality, first class direct-current machines, they will readily pick up as direct-current generators and can feed power into a suitably proportioned resistance. This method of braking is perfectly feasible, provided the controlling apparatus and car circuits are arranged for this purpose.

Consider, next, the case of feeding power back into the line and controlling it. It would appear when looking at the problem broadly, that a motor which could have its speed and power varied so economically over a wide range, should also be capable of reversing its functions and becoming a generator of power with an economical control over a wide speed range; and it has been determined in an extended series of shop tests, that the single-phase type of railway motor does possess this property under certain conditions. A number of ways of doing this in a more or less successful manner have been tried. Some of these methods are very effective and permit practically perfect control of the power and speed during braking, or when returning energy to the line. Such an arrangement would probably not be advisable for merely stopping trains. Its true field would be in letting a train down a grade of such length that the power is returned to the line for a long enough period to represent a fair proportion of the total time of operation. Both this method and that where the power is absorbed in a rheostat, are valuable in relieving the wear of the brake shoes, which is a very important item on very long grades.

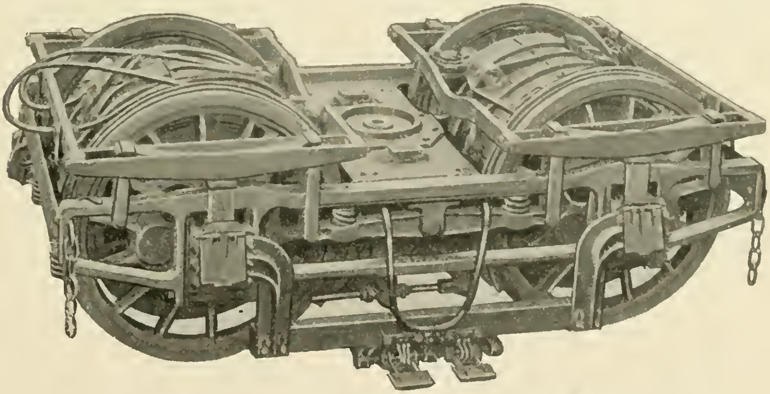
The resistance method of braking, although not as efficient as the other, has one advantage, in that it is independent of the supply system. Therefore, in case the power goes off when the train is descending a grade the resistance method of braking would still be effective.

In the past few months, two contracts have been taken by the Westinghouse Electric & Manufacturing Company for single-phase railway equipment involving locomotives of steam railway size.

These are for the equipment of part of the New York, New Haven & Hartford Railway system and for the electrification of the St. Clair or Sarnia tunnel, under the Detroit River, on the Grand Trunk Railway. The former equipment will operate under high speed passenger service conditions, while the latter approximates freight locomotive conditions. A brief description of these two proposed installations may be of interest.

THE NEW HAVEN SINGLE-PHASE EQUIPMENT

In this case the problem is somewhat complicated by the fact that the locomotives must operate on direct current over the New York Central part of the New Haven system, and on alternating current on its own part of the line. However, this complication is not nearly as great as would appear at first thought, for the type of locomotive chosen is one which adapts itself well to both classes of service. However, there is necessarily some duplication of parts on the locomotive, such as the collecting devices, certain details of the controllers, wiring, etc. On the other hand, it is surprising how many parts are common to both classes of service. As the New Haven equipment in its alternating part embodies many features which have been carried out further than ever before, it may be of interest to describe it as a whole.



ONE OF THE NEW HAVEN LOCOMOTIVE TRUCKS WITH MOTORS IN PLACE

GENERATING PLANT

The main power house is at Riverside, about three miles from Stamford. The generators in this power house are to be driven by steam turbines. The machines have single-phase ratings of 3 750 kw, or about 5 500 kw on three-phase, the armature winding being such that three-phase current can be obtained from the same machine. The generators have two poles and at 1 500 r.p.m. give 3 000 alternations per minute or 25 cycles per second. A 5 500 kw, three-phase, two-pole, 1 500 r.p.m. generator would have been considered an impossibility only a short time ago. The design of these generators was one of the difficult problems in this undertaking. The difficulty, however, was in designing the machines in the first place, and after a suitable construction was worked out, the manufacture of these machines appears to be comparatively easy. The machines have an ample margin, both electrically and mechanically, and they are particularly well adapted for handling inductive loads. As an illustration of unusual conditions met with in the design of such machines, I will mention that a single complete armature coil weighs about 600 pounds. However, as the machines have only two poles, the total number of armature coils is relatively small. As a machine in such service is liable to have rather heavy short-circuits at times, the armature end windings are extremely well braced.

As these machines are to feed directly into the trolley system, they are wound for the normal trolley tension of 11 000 volts, and in consequence one terminal of each machine is always grounded when in service, as in usual practice with direct-current railway generators. This point has been fully kept in mind in the design of these machines.

As the New Haven Railroad Company contemplates operating certain existing direct-current systems from this power house it was decided to add an additional leg to the armature winding so that three-phase currents could be obtained for feeding into rotary converter stations for furnishing direct current for some direct-current lines which, at the present time, cannot be conveniently changed to straight alternating current. The New Haven Company also has other fields for three-phase power which it proposes to take care of as soon as it is feasible to do so.

The steam turbines for driving these generators are of the well known Westinghouse-Parsons type. On account of the large output and high speed an unusually good performance is indicated. The engines are designed for the single-phase rating of the generators, as it is anticipated that the heavy service and the load peaks will be due to the railway load.

OVERHEAD TROLLEY SYSTEM

As 11 000 volts will be applied directly to an overhead trolley and as the trolley system will span from four to six tracks, it is evident that a very substantial overhead construction must be used. The construction of this overhead system is one of the most interesting features in this whole electrical system.

The trolley system is to be suspended from steel bridges which span from four to six tracks normally, and even a greater number at special points. These bridges are placed at intervals of about 300 feet and at points about two miles apart heavier structures, called anchor bridges, are placed.

The steel cables which support the trolley wire proper are supported by massive insulators on the bridges. Two cables are used for each wire and form a double catenary suspension carrying the trolley wire by means of triangular supports. The double system of suspension gives increased stiffness to the trolley construction. The triangular supports are placed about ten feet apart. The steel cables have a total sag of about six feet, while the trolley wire itself is maintained in a practically horizontal position.

At points corresponding to the anchor bridges; that is, about two miles apart, each trolley wire is broken by section insulators and is connected to the other trolley wires and to two feeder wires through automatic circuit breakers. Otherwise each trolley wire, with its cables and supports, is insulated from the adjacent wires. In this way each wire is sectioned and a short-circuit on any one section can be cut out without putting the neighboring wires out of service. The two feeder wires just mentioned are carried the whole length of the alternating system, and by means of these and the arrangement of automatic switches, any entire section of four or more trolleys could be cut out of service and the sections beyond can be kept in service.

The trolley wire has a nominal height of 22 feet above the track. This height will vary a few inches up or down with wide variations in temperature. The pantagraph type of trolley used on the locomotives has an effective range of about eight and one-half feet and therefore a very considerable variation in the height of trolley is permissible.

The overhead system is designed to be amply safe under abnormal conditions, such as high wind or heavy coating of ice. The stresses in the supporting cables with a load of ice one-half inch thick or one inch total, each side, on the cables, hangers, etc., will be about one-sixth of the ultimate. The stresses in the structure due to wind have been figured on a basis of sixteen and two-thirds pounds per square foot, projected surface for the cables and 25 pounds per square foot normal surface for flat surfaces. This is on a basis of the cables being covered with ice as given above. Allowance is made for double these pressures in summer when there are higher wind velocities, but under this condition the cables will be of much smaller diameter in the absence of ice.

As 11 000 volts is used on the trolley system, no transforming stations are necessary on the part which is now to be installed. The high voltage trolley system will extend about 19 miles in one direction from the power house and about three miles in the opposite direction to Stamford. This system could be extended in the latter direction approximately 20 miles further, if desired, without transforming sub-stations. Therefore about 40 miles of the trolley system can be supplied directly from the main power house. With a locomotive load representing 4 000 kw, about 19 miles from the power house and a corresponding load 15 miles away, or four miles from the power house, the drop at the end of the line will be about 13 per cent. This drop is on the basis of feeding into the load from one direction only. If there was a transforming sub-station about 40 miles away from the power house, feeding into the same trolley system, then the drop at a point 20 miles away would not be 13 per cent., but would be considerably less as power would be supplied from both directions. It is apparent, therefore, that with sub-stations along the line feeding into a common trolley system, such sub-stations could be possibly 60 miles apart. For example, if a transforming sub-station were placed in New Haven about 40 miles away from the power house, the drop at the midway point between the sub-station and power house would be equivalent to a load on the present system at 10 to 15 miles from the power house. However, the above distances between sub-stations are so great that it might prove inadvisable to feed more than one or two sub-stations from a given plant two or more power plants being installed on a very long system.

THE LOCOMOTIVE

This is the part of the electrical equipment which will doubtless excite the most interest, principally because it is a newcomer in an old field. From the standpoint of the designer the generating system and overhead construction may present just as interesting features, but to the layman in the electrical field there is but little with which to make comparison; but when it comes to the locomotive the general problem is much better understood.

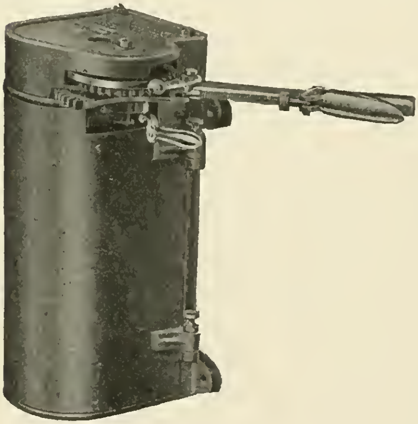
The frame, trucks and cab of this locomotive were built by the Baldwin Locomotive Company, on designs developed after many conferences between the New Haven Railway Company, the Baldwin Locomotive Company and the Westinghouse Electric & Manufacturing Company. The design adopted was partially determined by the fact that the motor equipment must be suitable for use on both alternating and direct current. This to a certain extent controlled the number and size of the motors and thus affected the construction of the trucks and other parts. The results have turned out so well, however, that there is every reason to believe that this type of locomotive will be used in future even where alternating current alone is used.

The mechanical construction of the locomotive presents many novel and interesting features which deserve special consideration. The running gear consists of two trucks, each mounted on four 62-inch driving wheels. The length of wheel base is eight feet. The side frames are of forged steel and to them are bolted and riveted the pressed steel bolster carrying the center plate. The weight on the journal boxes is carried by semi-elliptic springs with auxiliary coiled springs under the ends of the equalizer bars, to assist in restoring equilibrium. The bolsters are 30 inches wide at the center plate and are widened, where bolted to the side frames, to nearly double this amount, thus giving a very strong construction without excessive weight. The center plate which transmits the tractive effort to the frame is 18 inches in diameter and will be lubricated to permit a perfectly free motion in curving. The truck centers are fourteen and one-half feet apart.

Owing to the fact that the entire space between the wheels is occupied by the motors it was impossible to transmit the drawbar pull through the center line of the locomotive in the usual way. Instead of this, strong plate girders heavily cross braced are carried outside of the wheels and the entire strain of the drawbar is carried to these through strong box girders having top and bottom plates 42 inches wide. Directly underneath the girder at each end is a Westinghouse friction draft gear to which the drawbar is attached. The engine design lends itself to a very strong construction without great weight. The cab is built up of sheet steel on a framework of "Z" bars. The apparatus inside the cab is carried on a framework of structural steel which is built into the cab and firmly anchored to floor and ceiling. Over each motor is a large trap door which permits easy access to motor bearings, brushes, etc.

The motors are four in number, each of 250 hp nominal capacity but with a continuous capacity of over 200 hp each or over 800 hp total. The motors are of the gearless type and are wound for a normal full load speed of about 225 r.p.m. They are connected permanently in pairs and require about 450 volts at the terminals on alternating current and 550 to 600 volts on direct current.

The frame and field of each motor is split horizontally and can be removed in halves in order to give access to the inside of the field or to the armature. The armature is not placed directly on a shaft but is built up on a quill through which the car axle passes with about five-eights of an inch clearance all around. On this quill, at each end, are placed bearings which carry the field frame.



MASTER CONTROLLER USED ON NEW HAVEN LOCOMOTIVE

At each end of the quill is a flange from which projects seven round pins, parallel to the shaft, into corresponding pockets in the hub of the wheel. Around each pin is placed a coiled spring wound with the turns progressively eccentric. These springs are contained between two steel bushings, the smaller of which slips over the pin, and the larger fits in the pocket in the wheel. These springs are amply strong to carry the entire weight of the motor but are normally required to transmit only the torque of the motor and to keep the motor axis parallel to the axle. They allow a total vertical movement of about three-quarters of an inch. The end play of the motor, instead of coming directly on the wheels, is taken by strong coiled springs inside of the driving pins which press against covers in the outer ends of the spring pockets in the wheels. The torque on the motor frame is taken by heavy parallel rods which anchor the frame to the truck above and below the axle. These rods permit vertical or side motion of the motor but prevent excessive bumping strains from coming on the motor driving springs. The entire weight of the motor is normally carried on springs supported from a steel frame surrounding the motor and resting on the journal boxes.

The motors are internally of the same general type which the Westinghouse company has been building for some time for interurban service. However, due to the relatively low speed of the motors, the maximum commutator speed is very low, being less than 3 000 feet per minute when the locomotive is making 60 miles per hour. This may be compared with 5 000 to 7 000 feet commutator speeds which are frequently attained in both direct-current and alternating-current high speed service with fairly large motors.

One interesting feature in these motors is the method of cooling. As a blower is used in the locomotive for cooling the lowering transformers, it was decided to extend this method of cooling to the motors also. In the floor of the cab is an air conduit of considerable size from which air is piped to each motor. This method of cooling improves the continuous capacity of the motors, as evidenced by the above figures, which show that the continuous rating is almost equal to the one hour rating. A further very great advantage in this method of cooling lies in the fact that the motors can be kept very clean in this manner, as the inside of the motor is kept under partial pressure at all times, tending to keep out dust and dirt, as all air flow is outward. The air furnished to the motor, being taken from the inside of the cab, can be kept relatively clean and dry.

On the direct-current part of the line, current is taken from the third rail system, except in the case of some short sections at cross-overs fed from an overhead trolley on direct current. The motors are controlled in the usual series-parallel method in combination with resistance, as in ordinary direct-current practice.

On alternating current the motors are not operated in series-parallel as on direct-current, but are connected permanently in a given manner and the supply voltage is varied. This gives an equivalent of the series-parallel, except that the number of efficient operating steps is much greater. On alternating-current operation no resistance is used in regular running, but a slight amount is used in passing from one working step to the next, this being in the nature of a preventive device to diminish the short-circuiting effect when passing from one transformer tap to another. There are six operative voltages, or running points, on the alternating-current, corresponding to six taps on the lowering transformer, while there are a small number of intermediate steps, which are used only in passing from one working point to another. Experience has shown that the number of steps on alternating-current required to give a smooth acceleration is considerably smaller than required on direct-current. In consequence the controller is so arranged that on alternating-current about half as many steps are used as on direct-current. The tests have shown that the acceleration on both alternating-current and direct-current is very smooth.

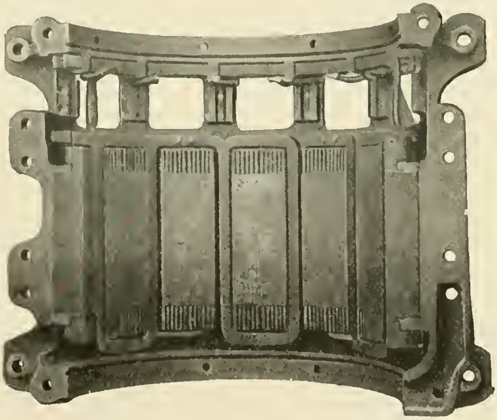
There is one feature in the direct-current control which is not generally found at the present time on direct-current equipments, namely, shunting the field for higher speeds. On the series position on direct current the motors have an efficient running point. It is usual railway practice to pass from the series to multiple position by introduction of resistance, there being no intermediate efficient running speed. On the New Haven equipments, however, the type of motor used is one which permits an almost indefinite shunting of the field without affecting the commutation or operation otherwise, and advantage is taken of this to obtain several higher speeds by shunting the fields before passing into multiple. In this way several efficient running points are obtained between the series and multiple. The tests have shown that these motors will operate in a perfectly satisfactory manner on direct current with their fields shunted down to much less than half their normal strength.

When operated on direct current, as stated before, the current is fed directly to the motors. On alternating current, however, step-down transformers must be used, as the alternating-current trolley voltage is 11 000. The step-down transformers are two in number, one on each side of the cab, in order to balance the weight in the cab. It must be borne in mind that these transformers are the heaviest single pieces in the cab and there would be considerable difficulty in placing a single transformer to advantage. A further reason for two transformers is that an injury to one would not entirely disable the locomotive. The transformers are connected in parallel across the high voltage side, but on the low voltage side each transformer feeds one pair of motors, through a separate control unit. This means that the controller when operated on alternating current consists of two normally independent units.

The main controllers are of the well known Westinghouse electro-pneumatic unit switch type. The design, however, differs somewhat from the straight direct-current type, due to the fact that switches, blow-outs, etc., must operate on both alternating and direct current as many parts of the controller are common to both. It may be mentioned also that the reversing switches are of the unit switch type.

The main controllers are operated from master controllers at each end of the cab. The controller system is arranged for multiple unit operation so that two or more locomotives may be coupled to the same load.

In addition to the controlling and transforming apparatus there are a number of auxiliary parts, such as two air compressors driven by motors which can be operated on either alternating or direct current; two blowers driven by similar motors, for furnishing air to the transformer and motors, and to the direct-current rheostat. It may be mentioned that the air which passes through the transformers is also sent through the rheostats. When operating on alternating current the transformer is heating the air which passes through, and this air would not be very effective in cooling the rheostat. However, when running on direct-current the transformer is idle, and the air passing through becomes effective in the rheostat.



FIELD AND FIELD WINDING FOR ONE-HALF OF A NEW HAVEN LOCOMOTIVE MOTOR

In addition to the above auxiliary apparatus there are oil circuit breakers for the high tension alternating-current switches for throwing from alternating current to direct current, and many details which would be found in any electric locomotive. There is also a steam generator in the cab for the purpose of generating sufficient steam for heating the coaches in cold weather.

The locomotive is equipped with devices for collecting both alternating and direct current. For the latter there are eight collecting shoes, four on each side of the locomotive, arranged in pairs of two each. There are, of course, two pairs on each side, one at each end, for the purpose of bridging such gaps as are necessary in the third rail system. There must be shoes on each side, as the locomotive must be able to make contact with the third rail when turned end about. These direct-current contact shoes must also be able to work on two forms of third rail, one in which the shoe runs under the rail and the other where the shoe runs on top of the rail. The locomotive is provided with a pantagraph low tension overhead direct-current trolley to conform with certain New York Central requirements.

For collecting alternating current the locomotive is provided with two pantagraph type high tension bow trolleys. Each trolley has sufficient capacity to carry the total line current under average conditions, but two are provided to insure reserve capacity.

Each of these locomotives is to be able to handle a 200-ton train in local service on a schedule of 26 miles per hour, with stops averaging about two miles apart. In order to make this average speed the maximum speed will be about 45 miles per hour.

One locomotive will also be able to handle a 250-ton train on through service. For heavier trains than this it is intended to couple two locomotives together and operate them in multiple. This presents no difficulties, for, as stated before, the locomotives are fitted up for the multiple unit system of control.

It is evident from the above description that the engineers of the New Haven Railway Company have had in view the adoption of an electric system which is particularly well adapted for future extensions. If the electrification were to stop at Stamford, then the full advantage of the alternating system would not be obtained. However, the section which will be electrified with alternating current is of sufficient length to enable the New Haven Railway engineers to determine the advantages and possibilities for future extensions, and it is safe to predict that such extensions will be made in a comparatively short time.

SARNIA TUNNEL

While this equipment is to be on a smaller scale than the New Haven, yet it is for an entirely different class of service and covers conditions not contemplated in the latter.

The part of the Grand Trunk Railway to be electrified consists of the Sarnia tunnel and its approaches. There is to be comprised about 4 000 feet of approximately level track at each end of the approaches, there is then a grade of two per cent. for 5 000 feet at each side and a stretch of 1 700 feet at the middle, which has just sufficient grade to drain itself. The total length of the electrified part will therefore be about 20 000 feet. The tunnel itself is slightly over 6 000 feet long. There is but a single track through the tunnel, although there are two tracks in the approaches.

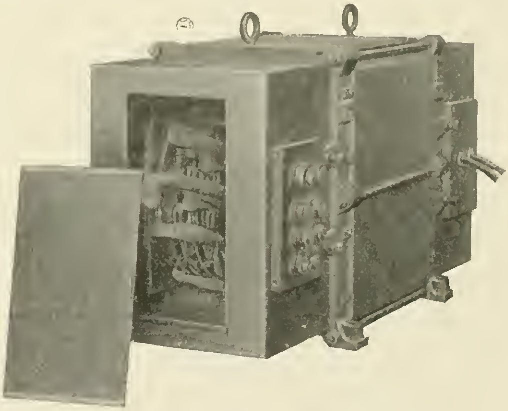
There are two conditions which have determined the electrification of this tunnel; namely, the difficulty from smoke and fumes from the steam locomotives, and also the present limit capacity which has been attained with the steam service now in use. At the present time a steam locomotive can handle a train of about 750 tons through this tunnel and there are about 40 trains per day each way. This represents the limits of the tunnel service with the equipment now being used.

In changing to electric operation it was determined that trains of 1 000 tons capacity could be handled instead of 750. It would have been possible to handle even heavier trains than this, as far as the electric motors are concerned, but it is considered impracticable on account of limiting conditions in the draw-bars of the individual cars. In the electric service contemplated, a train is to be made up in the yards at either end of the tunnel and the electric locomotives are then to take such trains through the tunnel and out on the level at the opposite end. Beyond this the steam equipments will handle the service.

The electric locomotives will take the train down the two per cent. grade and into the tunnel at a speed not exceeding 25 miles per hour. A fairly high speed will be maintained until the train strikes the up-grade at the opposite end. The speed the train has attained will assist, to a certain extent, on the up-grade, but in the major part of this grade the locomotive itself will be required to pull up the train. Under this condition the locomotive will develop about 1 500 hp at a speed of approximately ten miles per hour and it is designed to have power for maintaining this speed up the entire length of grade. This is a condition not attained with the present steam service.

Passenger trains can be taken through the tunnel at a considerably higher speed than the freight trains. On account of the characteristics of the motors used in this equipment it is practicable to make from 18 to 20 miles per hour on the up-grade instead of ten miles with the freight service.

The electric locomotive consists primarily of two so-called "units" coupled together. Each of these units has a nominal rating of 750 hp and each is complete in itself and can be operated independently of the other. Any two of them can be coupled together to form a complete locomotive and are then operated by one driver, the same as a single unit. More than two units can be coupled together and be operated as a single unit in the same way. One locomotive consisting of two units is required normally for the freight service specified above. For passenger service either one or two units may be used, as conditions may require. There will be five units at first in the Sarnia equipment.



ONE OF THE TWO STEP-DOWN TRANSFORMERS ON THE NEW HAVEN LOCOMOTIVE—LOW TENSION END

Each of the locomotive units is to be of a rigid frame type, with three axles, with a 250 hp motor geared to each axle. The weight of each unit will be between 60 and 65 tons, and one locomotive complete will develop a normal draw-bar pull of about 50 000 lbs. With sanded track it can develope about 25 per cent. greater draw-bar pull without slipping the wheels. Except that the motors are of the single reduction type, instead of gearless, they are very similar in general features of construction to the New Haven motors.

They are, however, somewhat lighter and smaller, as the armature speeds are slightly higher. These locomotives have somewhat simpler control equipment than the New Haven, due to the fact that they are to operate on alternating current only.

The overhead construction outside the tunnel is to be very similar to that of the New Haven system. In the tunnel, however, a trolley suspended at frequent intervals will be used, as it is not feasible to use the long spans in the space available. A voltage of 3 300 is used on account of the limited height of the tunnel. If it were not for this it is probable that 6 600 volts would be favored. However, as the entire length of this system is only about four miles and the trolley will be fed near the middle point, 3 300 volts is entirely permissible, especially as the heaviest service will be on the grades about midway between the center and the ends of the line. At the two ends of the line the service will be relatively light.

On account of the very intermittent load at the locomotive the variations of load on the power house will be extreme. There are to be two generators driven by steam turbines, either one of which normally will be able to handle the load. The other can be a reserve, or in case of extreme conditions it can be operated in parallel with the first. The generators are designed for normal single-phase operation but the armature windings are equipped with a third branch for three-phase operation, as on the New Haven equipment. There are certain pump motors and other apparatus which is designed to operate with three-phase induction motors and for this reason the additional winding was added to the generator.

Everything considered, this Sarnia Tunnel equipment is an extremely interesting one and the results obtained should have as important a bearing on future development as those from the New Haven electrification.

LOCOMOTIVE TESTS

About a year ago in the discussion of Mr. Potter's paper before the New York Railroad Club, I stated that the Westinghouse company was building a slow speed, single-phase locomotive of approximately 1 500 hp. This was designed for a normal speed of about ten to twelve miles per hour and a draw-bar pull of approximately 50 000 lbs. Shortly after this meeting this locomotive was put in active operation and very severe tests were made. It was attached to a heavy train of freight cars through a dynamometer car, and pulls up to 87 000 lbs. were indicated by the dynamometer. This locomotive was built for service corresponding to that in the Sarnia tunnel.

The Westinghouse company has also had the first New Haven locomotive on test in the Interworks Railway at East Pittsburg for a short time. Up to the present time, March 16th, this locomotive has made a total of about 2 000 miles on a track of approximately one mile in length, as this is all that is available at present. This means that this locomotive has started over 2 000 times, as a single run does not exceed one mile in length. Under this condition of operation this locomotive has handled trains of considerably over 200 tons for hours at a time. This is much harder service than the locomotive was designed for, as the starts are much more frequent. The results obtained so far have been very satisfactory and they agree very closely with the preliminary calculations. The locomotive rides very smoothly and the suspension used appears to have been perfectly successful in preventing pounding and shocks. The locomotive has taken rather sharp curves at a speed of almost 60 miles an hour. The locomotive has handled loads above the contract requirements for several hours at a time with temperatures well within the guarantees.

The above results were obtained when operating single-phase. On direct current the results are also very satisfactory, although very extended tests have not been made. All the results obtained, however, with both alternating current and direct current, indicate that this New Haven locomotive will prove a very satisfactory type, both electrically and mechanically.

SOME FEATURES OF THE WARREN GAS POWER PLANT

WARREN & JAMESTOWN STREET RAILWAY

J. R. BIBBINS

THAT the new power plant at Warren, Pa., has revolutionized ideas regarding the successful operation of gas engines is probably not an over statement to those who have been fortunate enough to see the plant in regular daily operation. To those experienced in the operation of steam plants only, and who have been possessed of the idea that steam engines alone were capable of meeting so severe a service as this, it would prove very profitable indeed to spend a day at the Warren plant. The following conditions occur in normal operation:

1. The load (consisting of three to five heavy interurban cars and a few small city cars) is most violent in character owing to heavy grades, sharp curves, and the small number of cars.
2. All generated power is on the alternating-current system, the generators being direct-connected without spring couplings.
3. The two 500 hp units operate in electrical parallel during the entire day's run on the above mentioned load.
4. No reserve steam power is available.

A study of these operating conditions brings forcefully to mind the opinions quite frequently expressed by the engineering world, and in the majority of cases, deciding against the use of gas power for continuous responsible service. In refutation, the Warren plant stands as an example of the successful use of gas power under operating conditions which would tax a steam plant to the utmost. Here is a plant which after erection in the field was immediately put into service, and with the exception of a few minor difficulties (always occurring in the starting of a large plant) has maintained an uninterrupted service since, although the engines had never been run or tested at the builder's works.

The decision to use gas power resulted from experiments started several years ago by the Warren Company using the natural fuel gas of which abundant supplies exist in this neighborhood. The results were so much better than would have been possible with gas fired boilers and steam machinery as to practically dictate the adoption of large gas engines for running the new single-phase system. How successful the new plant has been, from a commercial standpoint alone, is evidenced from the data obtained through two months' run. During December, only the interurban system was being operated from the new power plant. During January both interurban and city systems received their power from this source. (See Table I.) Previous to the combining of the two systems the old plant was used to run the city cars. After the city load had been put on to the new plant a saving of approximately 20 per cent. in fuel was realized over the old arrangement. Assuming the interurban cars to make an average mileage of 15 miles per hour, including lay-overs, the average cost of fuel per car mile in December was under one cent, and at the present time is even less than this. That the cost of fuel, even at this low rate, will constitute the major part of the operating expenses is evident from the fact that the entire plant is operated by two men to a shift, with a third man during the day as general helper.

TABLE I.

COST OF OPERATION.

1000 hp. gas engine plant, Warren & Jamestown railway.
Interurban system only.

December, 1905.	
Number of cars (35 ton)	3
Gas consumed	1 701 000 cu. ft.
Gas per day averaged	54 900
Hours operated per day	17.5—18
Gas per hour (operation)	3 090
Cost of fuel per day	$8.24
Cost of fuel per hour run	0.464
Cost of fuel per car hour	0.155

Interurban and City systems.

January 5-12, 1906.	
Number of cars—city (10 ton)	7
Number of cars—interurban (35 ton)	3
Gas consumed	625 000 cu. ft.
Gas per day	89 285 “
Hours operated per day	18
Gas per hour(operating)	4 960 “
Gas per hour (operating)	4 960 “
Cost of fuel per day	$13.40
Cost per hour run	.744
Cost per car hour	.0744

Interurban and city systems.

Month of January, 1906.	
Number of Cars—city (10 ton)	7
Number of cars—interurban (35 ton)	3-4 Av. 3-½
Gas consumed	2 745 000 cu. ft.
Gas per day	88 550 “
Hours operated per day	18+
Gas per hour (operating)	4 900 “
Cost of fuel per day	$13.27
Cost per hour run	.735
Cost per car hour	.07

THE GAS ENGINE EQUIPMENT

There are two generating units installed at the present time with space for a third as soon as required by the demand for power. The engines are normally 500 hp in capacity, but on the standard rating adopted by the builders of ten per cent. overload, the actual rating is 470 hp with a maximum of 520. This conservative rating corresponds to a maximum overload capacity of 35 per cent. on the generator. For more uniform loads in which violent fluctuations would not occur, a higher electrical rating would be possible. The engine has two tandem cylinders 21 inches in diameter by 30 inches stroke, supported entirely clear from the foundation piers by front, middle and rear housings, as shown in Figs. 1 and 2.

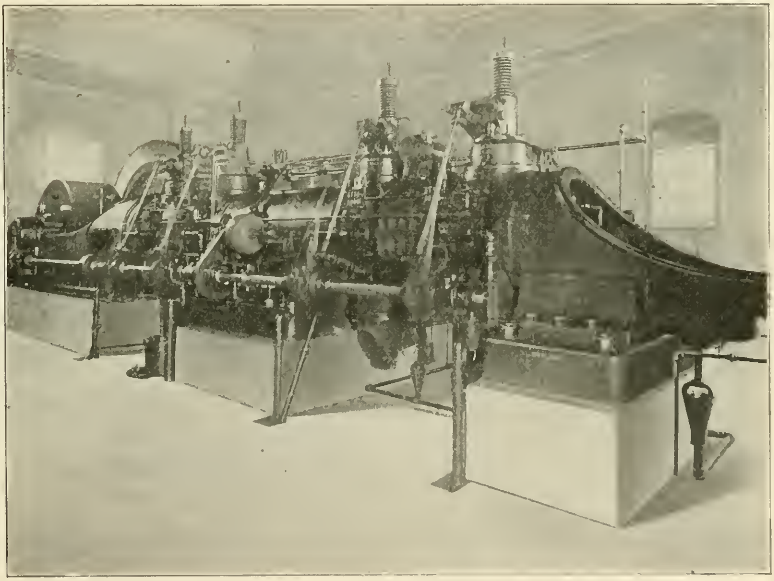


FIG. 1—GENERAL VIEW OF WARREN AND JAMESTOWN GAS ENGINE

Operating on the familiar Beau de Rochas or four-stroke cycle, with practically a constant quality of mixture, this tandem arrangement gives one power impulse on each forward and backward stroke, resulting in a crank effort equivalent to that of a single cylinder double-acting steam engine; in fact, the general design of the engine is characterized by its strong adherance to approved steam engine practice and it stands not as an example of radical change in structure, but as an adaptation of steam experience to gas work. This resemblance is further borne out in the indicator cards shown in Figs. 3 and 4. The stop card, Fig. 4, is intended to magnify the lower part of the indicator card to show more in detail the induction and exhaust lines of the four-stroke cycle. It was, of course, taken with a stop on the indicator to check the upward movement when a lighter spring was used.

Every part of the engine is above the floor level, including exhaust valves, which gives the engine an appearance of exaggerated size in reference to the generator. The three housings rest on sole plates capping their respective piers, and only the front end of the engine is anchored. The remaining parts slide back and forth on these sole plates as the engine expands and contracts on starting up and shutting down.

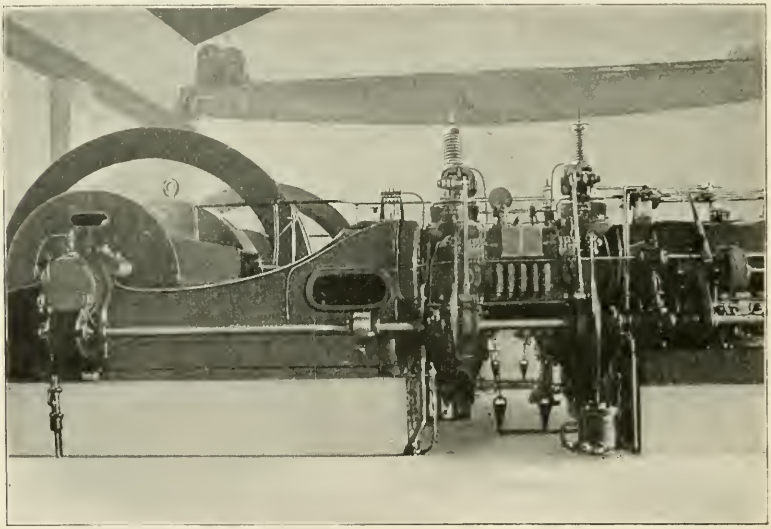


FIG. 2—SIDE VIEW OF FORWARD END OF WARREN AND JAMESTOWN GAS ENGINE

The pistons which are mounted on hollow rods of forged nickel steel are floated entirely free from the cylinder body by means of front, center and rear crossheads, and the pistons, rods, cylinders, valve chambers, cylinder heads, packing glands, and exhaust valves are all water cooled to prevent overheating of the metal.

All valves are of the poppet or mushroom type, arranged with inlet above and exhaust below in a vertical line; thus by removing these valves the cylinder is easily accessible for inspection or cleaning without dismantling the cylinder head. In the inlet valve a compound motion is employed by which gas and air are not only proportioned properly, but the quantity of mixture is also adjusted to the particular load, somewhat in the manner of a steam admission valve on a throttling steam engine. Each valve is directly under governor control, and thus receives only such amount of mixture as needed at the instant to maintain proper speed.

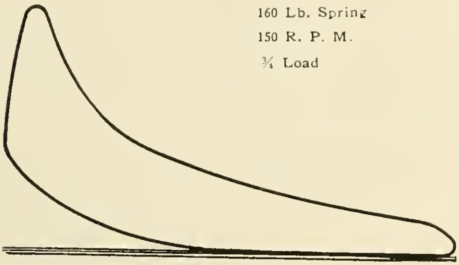


FIG. 3—INDICATOR CARD FROM ONE OF THE GAS ENGINES AT THE PLANT OF THE WARREN AND JAMESTOWN RAILWAY

The governing system has proven very effective. By the use of the relay principle the actual work of moving valves is assumed by a small piston working under oil pressure; this in turn is controlled by a little pilot valve which alone is actuated by the governor. This principle has already been applied successfully to the Westinghouse-Parsons steam turbine, and makes possible a speed regulation even lower than is desirable for practical parallel operation.

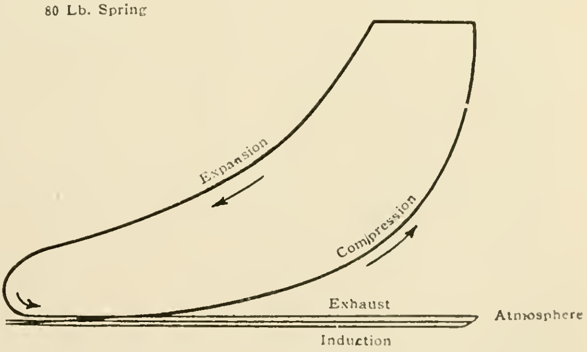


FIG. 4—INDICATOR CARD TAKEN WITH STOP AND LIGHTER SPRING THAN FIG. 3

In the exhaust valve mechanism, though a peculiar combination of levers, great power is exerted upon the exhaust valve at the point of opening followed by maximum speed of lift as the valve leaves its seat. These characteristics are shown by the curves in Figs. 5 and 6. The necessity for some gear of this kind is evident from the indicator card, which shows that the exhaust valve must open under a pressure of about 30 lbs. per square inch.

IGNITION

Electrical ignition is employed throughout the engine, both storage batteries and a dynamo being available for this purpose. By separating the circuit into two sections and providing double igniters at each cylinder end, there are four possible igniter combinations for each combustion chamber which renders improbable a shut-down from igniter sources. A small switch interposed in these igniter circuits is located at the rear end of the engine and another at the flywheel (the latter operated by a special limit device) ; either switch when opened will cut off the ignition current to the engine. This affords a convenient means of instantly shutting down the plant in case of necessity.

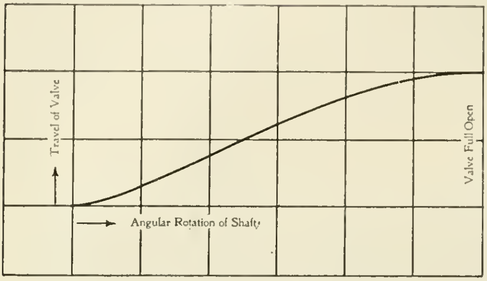


FIG. 5—VELOCITY CURVE FOR EXHAUST VALVE GEAR

CIRCULATING WATER

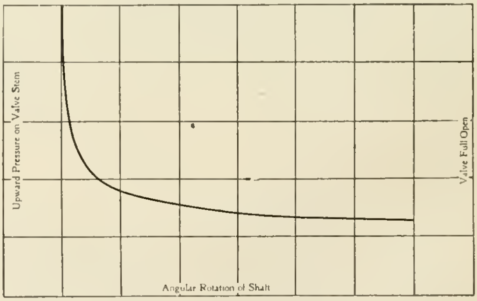


FIG. 6—PRESSURE CURVE SHOWING ACTION OF EXHAUST VALVE MECHANISM

Valve full open at right end of curve.

For this important service an automatic system is used. Water is supplied to the several parts of the engine at a constant head from an elevated tank, kept full by a motor-driven pump. This pumping outfit has an automatic motor starter controlled by the water level in the tank, which renders the water system automatic in its operation and relieves the attendant of much responsibility. At the engines open funnels are inserted in the outlets from the cooling passages as shown in Figs. 1 and 2, so that one may see as well as feel the condition of the water passages. Water is delivered to the piston rods by a small reciprocating plunger pump bolted to the crosshead. With this device water circulation in the piston begins at once when the engine is started.

LUBRICATION

The very vital detail of lubrication is entirely automatic in its operation. Small sight feed pumps, positively driven from the lay shaft, inject cylinder oil into the cylinder at just the proper time to prevent its lubricating properties being destroyed by the succeeding combustion.

Engine oil is handled by a continuous circulating and filtering system, comprising an elevated tank and flush sight feed manifolds on the engine.

STARTING

An effective detail is the mechanism whereby these engines may be started cold and brought up to speed with but two movements—the opening of two valves; one the compressed air and the other the gas supply. By means of special cams, compressed air is let into the cylinders at just the proper time to effect a power stroke. On the third revolution one of the cylinders automatically "picks up" the normal ignition and one by one the air starters are automatically cut off. With an engine of this size it usually takes about a minute to bring it up to speed from a cold start.

From this description some idea may be had of the details which have contributed to the successful use of gas power at Warren. This plant may well be considered as a mile-stone in the history of American gas power applications, as here for the first time is a complete demonstration of its ability to meet the severe conditions imposed by railway work. In combination with the single-phase interurban railway the Warren plant is altogether unique.

POTENTIAL REGULATION FOR LARGE ELECTRIC FURNACES

H. R. STUART

ELECTRIC furnaces for the manufacture of carborundum graphite, and similar products require a relatively high potential at the start. As the charge in the furnace becomes heated, its resistance decreases; it is therefore desirable to decrease the potential at the furnace terminals and at the same time to increase the flow of current thus keeping the kilowatt consumption nearly constant. The regulation of the current supplied to the earlier furnaces, when comparatively small amounts of power were required, was a simple matter. Devices similar to those commonly employed for the regulation of alternating-current, single-phase feeder circuits were successfully employed. But as the amounts of power required, and consequently the currents to be handled, became larger, the limit of these devices was soon reached and a demand arose for a regulating outfit of much larger capacity.

The type of feeder regulator mentioned above consisted usually of a transformer having a number of taps brought out from the secondary winding to contacts on a dial. A swinging arm connected to the main circuit could be shifted over these contacts.

The primary winding was designed for constant potential and therefore the induction in the iron core remained constant, while the number of secondary turns was varied to accomplish the desired regulation. This method gives a minimum of weight and therefore a transformer of low cost, but the dial or regulator must be in the secondary circuit, and when large currents are used, difficulties are encountered which make it advisable to resort to other means of regulation.

An excellent method consists of placing the regulator in the constant potential primary circuit of the transformer and varying the number of primary turns. In this way the currents handled by the regulator may be reduced to a convenient amount. The secondary turns remain constant, but the induction in the iron core is varied. Thus for a given output a somewhat larger transformer is required, but this is offset by the better design and performance of the regulator.

With the induction regulator these same objections do not exist, but other disadvantages are encountered, chief of which are; the larger magnetizing current, vibrations tending to injure the insultation and difficulty in bringing out the secondary leads so as to have them interlaced.

One of the problems met with in the design and operation of electric furnaces is the inherently low power-factor at which the apparatus works. This is due to the very heavy currents and the necessarily large area enclosed by the secondary circuit. To minimize this effect the secondary leads should be composed of a large number of straps so interlaced as to neutralize self-induction as much as possible. It is advisable also to have regulating devices which require small magnetizing currents as the working power-factor is thereby improved.

The induction regulator has been used for the control of large currents over a considerable range of voltage, but it has been practically supplanted in this field by the transformer with taps and regulator. Two installations of the latter type will be described.

A 450 kw. regulating outfit was installed at the Niagara Falls works of the Acheson Graphite Company about five years ago. This consists of a transformer, the primary of which has taps brought out and connected to a series of manually operated knife switches, the secondary being connected directly to the load. The constant potential 2 200 volt line may thus be connected to a varying number of primary turns and the regulation effected by changing the transformer ratio. The switches are mounted upon a marble panel with barriers interposed and are arranged to be operated by means of a pole and hook.

A preventive resistance* keeps the working circuit from being opened when the switches pass from one point to another, but it is not in circuit continuously. This arrangement gives an efficient and comparatively simple means of regulation, but it requires a skilled operator and considerable time to pass from minimum to maximum current, and vice versa.

Later a regulating outfit of nominally 1 600 kw. capacity was required by the Carborundum Company at Niagara Falls. This installation was to be operated from the Niagara Falls Power Company's circuits at 2 200 volts and 25 cycles.

It was desired to obtain a range of secondary potential from 150 to 75 volts with a practically constant current of from 700 to 800 amperes. This would give a current through the furnace of from 11 000 to 12 000 amperes according to the stage of the process. Owing to the lack of precedent it was not possible to determine exactly the secondary potential which might be required nor to what degree it would be necessary to graduate voltage steps for the best operating conditions. Although automatic overload protection was to be used it was thought best on account of the large currents to be handled to have the regulating apparatus "foolproof," so that an ordinary operator could be entrusted with its care. It was also desirable to pass quickly from one extreme to the other of its working range without danger of closing the wrong switch. After a careful consideration of the problem it was decided to employ a main regulating transformer, having taps brought out from points in the primary winding that would give approximately equal voltage steps on the secondary. In connection with these taps an oil-switch regulator, Fig. 1, capable of carrying the full line current and of transferring it without interruption from one tap to another, was employed. This was operated by means of a single handle; one direction of rotation raising and the opposite direction lowering the ratio of the main transformer.

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*The Electric Journal, Vol. II, p. 527.

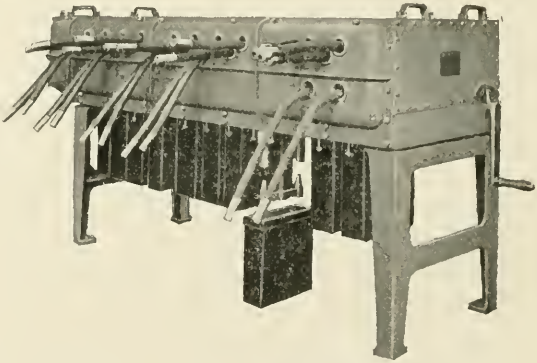


FIG. 1—MAIN OIL-SWITCH REGULATOR

The secondary winding, which was made up of a number of copper straps, was connected permanently to the furnace terminals. These straps were interlaced in passing from the winding and the interlacing was continued in the terminal straps to a point as near the furnace as possible, for the purpose of reducing the secondary self-induction as previously explained.

In order to secure a finer voltage adjustment an auxiliary regulator, Fig. 2, in connection with a series transformer and an autotransformer were supplied. This regulator was provided with a reversing switch making it possible to obtain the desired range of regulation with the minimum capacity of auxiliary apparatus. A preventive resistance was employed and all voltage changes made without breaking the circuit substantially as with the main regulator.

By referring to the diagram of the electrical connections, Fig. 3, the various steps in the operation of the apparatus may be followed. Consider switches 2 and 10 of the main regulator closed; upon turning the operating handle in the direction "to lower," a cam on the closing shaft closes switch 9, and a cam on the tripping shaft will then trip switch 10. Then switch 1 will be closed and switch 2 opened. These operations will take place in the order named and well within one complete revolution of the operating handle or crank. By following out the steps it will be seen that the line lead has been transferred from tap 10 to tap 9 of the main transformer by passing the main current through the preventive resistance R_1 for a very short time and without opening the main circuit or producing a disturbance on the line or appreciable arcing within the oil switch tanks. Another revolution of the handle in the same direction will transfer the line to tap 8. In this way all

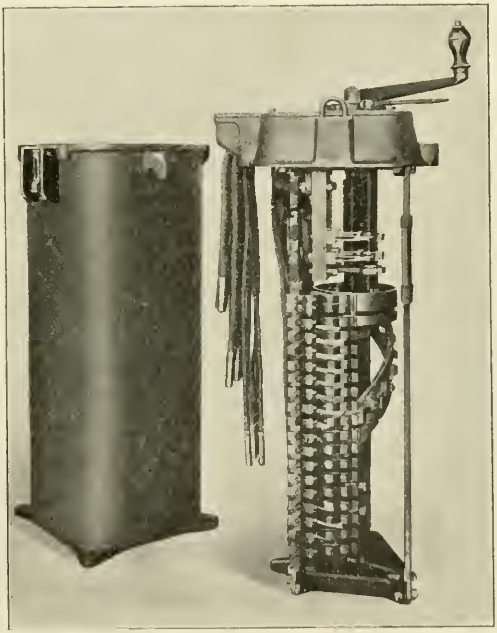


FIG. 2—AUXILIARY DRUM CONTROLLER

of the primary winding may be connected in and the ratio of the transformer so changed as to give the minimum potential at the furnace terminals. After turning the handle any number of revolutions "to lower," it may be turned in the reverse direction "to raise," which will simply transfer the line lead along the primary winding in the reverse direction.

The auxiliary regulator shown in Fig. 2 is of the drum type, with the drum made in two separate spiral castings. A preventive resistance R_2 is connected as shown in Fig. 3 and the circuit is not broken in passing from tap to tap of the auto-transformer. The reversing switch is mechanically interlocked with the drum so as to prevent its being thrown while the drum is in any but the first or zero positions.

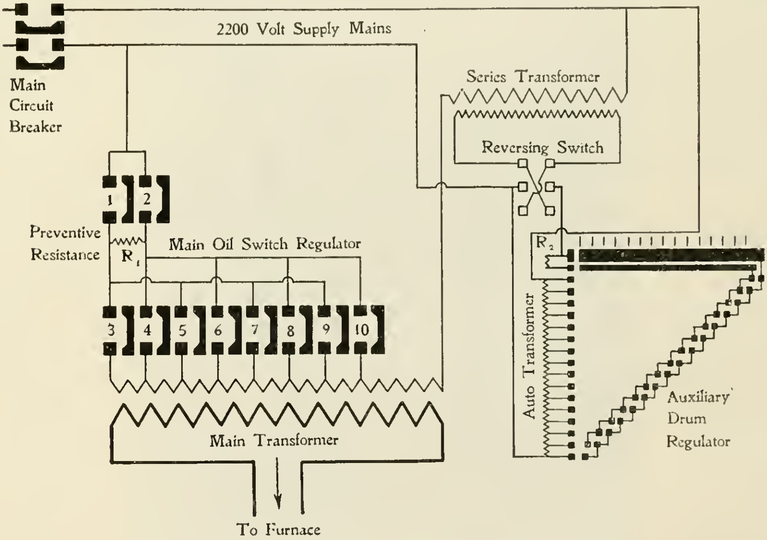


FIG. 3—DIAGRAM OF CONNECTIONS

The installation as shown in Fig. 4 was erected in 1903 and has been in continuous and successful operation since that time.

The supply mains may be seen on the wall at the left. One of these passes through a water rheostat and circuit breaker, which is mounted upon a shelf against the brick wall above the other apparatus. This water circuit breaker consists of a boiler-iron tank as the fixed element, having a vitrified sewer pipe as a lining for the sides and a pair of iron plates arranged as the moving element. The tank is partly filled with a saline solution. The moving element is arranged to be raised and lowered by means of a hand windlass mounted upon the side of the auxiliary regulator. A two-pole knife switch mounted against the wall is mechanically interlocked with the windlass and circuit breaker and electrically so connected as to short-circuit the water circuit breaker under regular running conditions and to be opened before the circuit breaker is opened. This combined rheostat and breaker serves to close and open the circuit gradually and to save the oil circuit breaker from undue wear.

The line next passes to a switchboard panel, through a two-pole automatic oil circuit breaker and the instruments to the regulators. The instruments on this panel consist of a 1 200 ampere ammeter, a 150 volt voltmeter for the low tension or furnace circuit and a 2 400 kw indicating wattmeter. The transformer case shown in the foreground contains the series and auto-transformers and directly beyond it may be seen the auxiliary drum regulator. Beyond the switchboard panel is the main regulator, with leads passing upward and back to the main transformer. The low tension secondary leads pass from the main transformer directly back through the wall to the furnace, which is located as near the wall as possible.

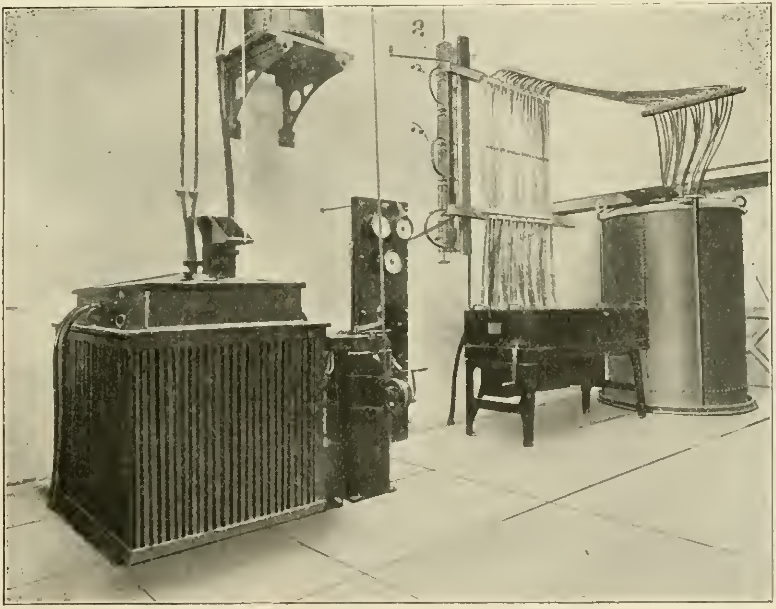


FIG. 4—GENERAL VIEW OF INSTALLATION

A door just behind the transformer opens into the furnace room. This is entirely shut off from the regulator on account of the dust and dirt incidental to the process.

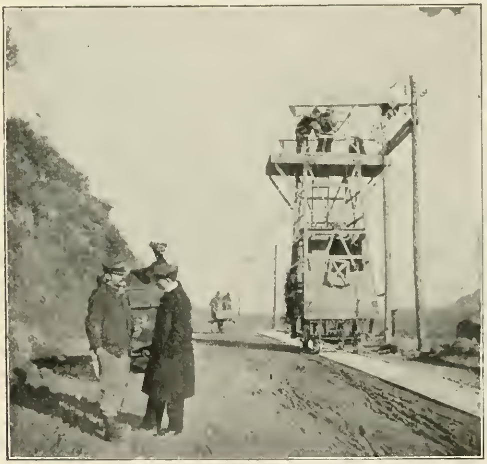
THE CIVITA CASTELLANA SINGLE-PHASE RAILWAY

W. R. STINEMETZ

THE first single-phase railroad in Italy was put in operation about the first of April, 1905, and extends from Rome to the town of Civita Castellana, a distance of 54 kilometers (34 miles).

The line for the entire distance is single track, and is laid on the public highway where still may be seen portions of the old Via Flaminia, the stone road built by the Romans.

This road winds its way through a very picturesque but hilly country, passing through several small towns, and contains many sharp curves and stiff grades. There are some grades of as much as seven per cent. and several curves of 20 meters radius (65.7 ft).

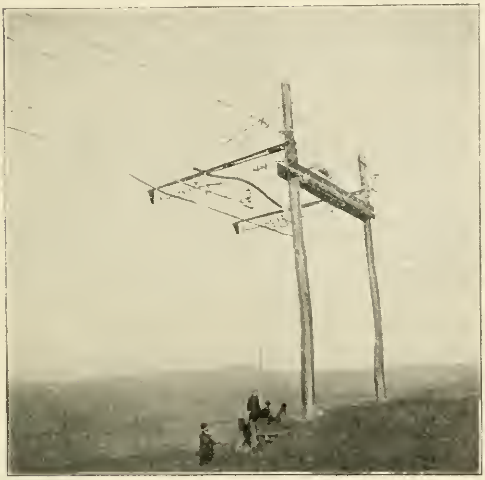


VIEW ON CIVITA CASTELLANA RAILWAY SHOWING WORKMEN INSTALLING A SECTION INSULATOR

Civita Castellana, at the end of the line, stands on a high bluff of solid rock and is well named with its strong walls and impregnable position. The road here has a seven per cent. grade with short curves for more than a kilometer (five-eighths of a mile). It has heretofore been isolated from railroad travel and all traffic is conducted by carts to the steam road, a distance of ten kilometers (6.2 miles).

Starting in the center of the more modern section of Rome the track is laid with a girder rail weighing 30 kilos. per meter (70 lbs. per yard) and a one meter gauge, (3 ft. 3.4 in.) both rails being bonded. The trolley voltage is 600, the line construction being of the standard 600 volt bracket type with a No. 00 grooved trolley wire and a feeder of the same size.

At the power station, which is situated along the banks of the Tiber river, about four kilometers (2.5 miles) from Rome, the rail is changed to T-rail of 20 kilos. per meter (50 lb. per yard) and only one rail is bonded. The line pressure is here raised to 6 000 volts and continues so to Civita, no feeder or sub-station being used, with the whole current carried on a single No. 0 grooved trolley wire suspended from brackets with double insulation.



VIEW OF CIVITA CASTELLANA RAILWAY SHOWING LINE CONSTRUCTION AT A SECTION INSULATOR

The bracket arm is made of two single-iron bars put together by plates to form a V, the open end embracing the pole on either side., to which it is fastened by means of a bolt through the pole, a collar of iron being placed around the pole at this point to prevent wear.

The two outside insulators are of the ordinary type of double petticoat insulator tested for 20 000 volts. A novel feature of this construction is the strain insulator used. The failure of this insulator to stand the mechanical strain, though it was good for the voltage test of 20 000 volts, necessitated immediate action as no other insulator could be found on the market. The trouble was overcome by putting this insulator in a cage, thus having a compression instead of a strain.

VIEW ON CIVITA CASTELLANA RAILWAY SHOWING LINE CONSTRUCTION AT TURN OUT

The cross suspension is made with steel cable with a flat bar in the center of the suspension. To this are attached the mechanical ears, made of steel, which hold the trolley wire. These ears can be adjusted at any point on this bar, the purpose of which is to obtain an easy method of staggering the line as is necessary with a bow trolley. By varying the length of this bar at curves it is also possible to adjust the wire properly without the aid of pull-offs.

Another point which is not used in ordinary construction is the method of suspending the trolley wire at the brackets. In addition to the ordinary suspension there is a short piece of cable clamped to the trolley wire about 70 c.m. (27.6 in.) on either side of the bracket, passing over and fastened to the same. This cable is normally a little slack but it serves the purpose of holding the trolley wire, should it break loose from any of its supports.

At every five kilometers ($3\frac{1}{8}$ miles) a section line insulator, a horn type lightning arrester with resistance and a three-pole switch are placed in the line, the ground plate for the arrester being also connected to the rails at this point. This sectional insulator is placed between two poles three meters (9.9 ft.) apart as shown. A double insulator is inserted in the trolley wire between these two poles and the same is anchored and elevated by means of an iron brace which spans the two brackets, the trolley bow being guided by the T-rod, which is shown to one side of the wire. This rod, which has an ordinary trolley wire riveted to the under side, is connected to one pole of the three-pole switch, while either side of the trolley is connected to the other two poles. In this way the circuit is continuous when the switch is closed. In order to render a pressure of 6 000 volts permissible on a public road, it was necessary to employ such a system that should the trolley break down or the circuit be opened at any point on the line, the current would be cut off at the power house. To obtain this result, there is a pilot wire of 2 mm. (.04 in.) diameter run from the power house to the end of the line where it is connected in series with the trolley wire. At the power house the pilot wire is connected to a minimum and maximum relay on the main circuit breaker and serves the purpose of opening this breaker should any interruption to the current occur either by an open or short-circuit in the line.

The cars to be operated on this line are the ordinary type of about 12 tons loaded, with small bodies and large platforms front and rear. They will be equipped with the standard Westinghouse single-phase apparatus consisting of two 40 hp single-phase motors of 25 cycles and 250 volts, with hand operated control. The autotransformer is of the oil type and has taps for the two trolley voltages of 6 000 and 600, with auxiliary taps for the motors ranging from 150 to 250 volts. There will also be a complete Westinghouse air brake equipment with motor operated compressor and a pneumatic bow trolley.

The change-over switch which is used in passing from the 6 000 to the 600 volt section as they enter the city of Rome, will be placed on the car roof at one side of the trolley base. The action of this switch is made mechanical by means of an L-lever which engages a spring brace on the pole when the car enters the dead section of the trolley wire. By this means the switch is thrown to either the 600 or the 6 000 volt position on the transformer according to the direction of the car.

In addition to these cars, of which there are seven, they are now building two locomotives for use in handling the freight traffic. These will be equipped with four 40 hp single-phase motors, automatic control with unit switches and geared to a speed of 20 kilometers (12.5 miles) per hour, the passenger cars having a speed of 40 kilometers (25 miles) per hour.

While this is the first Westinghouse road which will be put in operation in Europe, there are already under construction two much larger roads which will use the locomotives for all classes of service.

THE VARIATION OF CANDLE-POWER DUE TO FREQUENCY

EXPERIMENTS SHOWING THE VARIATION AT 25 CYCLES*

P. O. KEILHOLTZ AND B. HARRISON BRANCH

THE amount of variation of candle-power of incandescent lamps, due to a frequency at twenty-five cycles, has been a matter of opinion among engineers. This investigation was undertaken to determine definitely the amount of variation in illumination through the cycle. The practicability of 25-cycle lighting has been demonstrated at the Pan-American and the St. Louis Expositions, and it is in commercial use at Niagara Falls and in the city of Buffalo. The elevated stations of the Interborough Rapid Transit Company, in New York City, are lighted by incandescent lamps at 25 cycles.

In these examples the prime movers have a minimum variation from uniform angular velocity. Some new elements are brought into the problem when the prime movers have a greater angular velocity, which may in turn cause disturbances in parallel operation between themselves and other synchronous apparatus. The practicability of 25-cycle lighting, like that by direct current and higher frequency, depends upon the quality of the installation, and can best be determined in a particular case by actual trial.

The fundamental element underlying the fluctuation in candle-power is the fact that the temperature of the filament and the quantity of the light given off varies through the cycle. The first thing to determine, therefore, is the exact amount by which the candle-power varies due to frequency with both high economy and low economy lamps.

When an incandescent lamp is turned off the filament requires an appreciable time to cool and become black. If the circuit is rapidly made and broken the shade of red, which the filament assumes, depends upon the rapidity with which the current is interrupted; the shorter the period, the brighter the shade of red, and vice versa. An alternating current will produce a similar effect on the filament, causing a flickering of the lamp at low frequencies, but a steady light when the frequency is sufficiently high to maintain the filament at incandescence.

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*These experiments were performed by Mr. Branch, under the direction of Mr. Keilholtz, Engineer, Consolidated Gas, Electric Light & Power Company, Baltimore, Md

ARRANGEMENT OF APPARATUS

In order to determine exactly what is the variation in the intensity of illumination of an incandescent lamp on a 25 cycle, alternating-current circuit a number of experiments were performed, one of which may prove interesting and is as follows:

Two incandescent lamps were compared photometrically, one supplied from an alternating, the other from a direct-current circuit. The comparisons were made at a number of points in a cycle, by shading the photometer screen and admitting the light from both lamps at fixed intervals only. This was accomplished by rotating a disk with two radial slots diametrically opposite, between the lamps and the photometer screen. The photometer and lamps were mounted on a frame free to rotate around the same axis as the disk revolved. When the speed of the disk was synchronous with the alternating current, the lamps were exposed to the photometer at the same interval of the cycle, for a fixed position of the photometer. By rotating the photometer the exposure was made at other fixed periods in the cycle. Attached to the photometer was a circular disc graduated in divisions of five degrees each, and to the base was fixed a point to indicate the angular position of the photometer. On the same shaft as the disc was a circular scale divided into ninety degrees, making it possible to compare the lamps through any quadrant of the cycle, without changing the position of the disc on the shaft. The movement of the photometer was limited to one hundred and ten degrees in the apparatus used, necessitating a change of position of the disc on the shaft to cover a complete cycle of the incandescent lamp. The arrangement of the apparatus and circuits is shown in Fig. 1. The radial slots in the disc extend over an angle of ten degrees, exposing the lamps to the screen for 1/36 of a cycle. The potential across the terminals of each lamp was kept constant by means of variable resistances in each circuit.

The bi-polar synchronous motor and the alternating-current lamp were fed from the same transformer and therefore were subjected to the same variation in potential. The direct-current lamp derived its supply from a rotary converter, which was fed from the same high tension lines as the alternating-current lamp.

It was noticed that lamps were more readily compared when their filaments had the same relative position with respect to the disc. A filament in the position of maximum illumination when compared with one in the position of minimum illumination gave different colors to the spot, and for this reason made comparison difficult. The lamps compared were taken from stock and not specially selected.

The position of the disc on the shaft was such that the photometer scale and frame supporting the lamps was in a horizontal position for maximum candle power of the alternating-current lamp. This permitted a movement of fifty-five degrees on either side of the maximum point, making it possible to determine the shape of the wave peak without changing the position of the disc on the shaft. To obtain the minimum candle power the disc was rotated 90 degrees on the shaft.

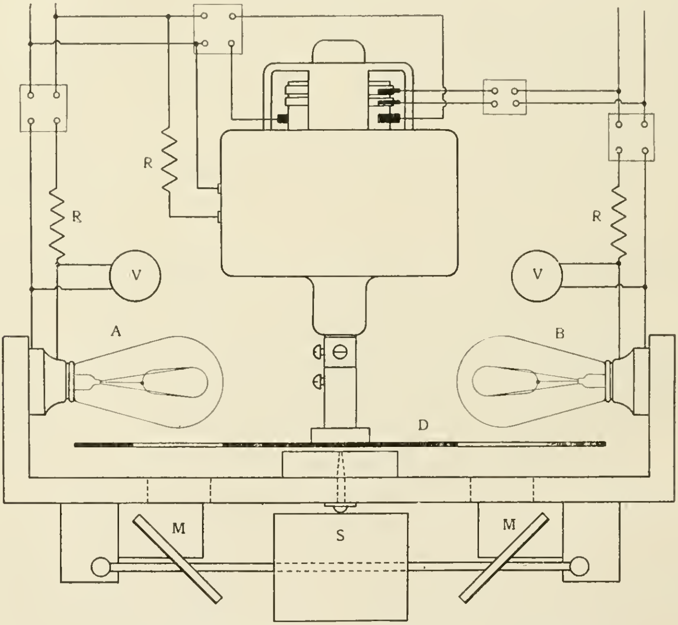

FIG. I—ARRANGEMENT OF PHOTOMETER AND CIRCUITS

A—Lamp on direct-current circuit
B—Lamp on alternating-current circuit
R—Variable resistance
V—Voltmeter
D—Slotted disc
M—Mirror
S—Screen

METHOD OF OPERATION

With the lamps in position, and the disc revolving at 1 500 r.p.m., the synchronous speed, readings were taken every ten degrees, for one hundred and ten degrees, when the disc was shifted ninety degrees on the shaft and the readings continued. The observations were made in a darkroom with the photometer screen shielded from stray light. The voltage on both lamps was maintained at normal, viz., 100 volts alternating current, 120 volts direct current. The readings of the photometer scale were corrected by adding a constant to give the distance of the direct-current lamp from the point of equal illumination. Knowing the length of the path of light, the relative candle-power of the two lamps was calculated by applying the rule that the candle-power of a lamp varies inversely as the square of the distance.

The lamps were then photometered to determine their candle-power in the direction in which they were compared and also rotating to ascertain the mean horizontal candle-power and watts per candle at their normal voltages. The candle-power of the direct-current lamp in its fixed direction was multiplied by the calculated ratio between it and the alternating-current lamp to give the candle-power of the alternating-current lamp in the several positions of the cycle at which comparisons were made.

RESULTS

The result of these observations for the four lamps compared are given in Figs. 2 and 3 which give the curves of candle-power at different points in the cycle of 3.1 watt and 4 watt, 16 candle-power 100 volt lamps; also 3.1 watt and 4 watt, 32 candle-power, 100 volt lamps.

The descending side of the wave is convex, while the ascending side is concave. This is more marked in the 3.1 watt lamp than in the 4 watt lamp which have heavier filaments and therefore do not respond as readily to a change in current density as the lighter filament lamps. The peak of the wave is more acute than the trough, which is to be expected; having a higher temperature the radiation from the filament is more rapid and so it responds to a change in current more readily.

The 16 candle-power, 3.1 watt lamp has a greater variation in candle-power than the 4 watt lamp or the two 32 candle-power lamps. This is due to the fact that the mass of filament and its surface is considerably less than that of the other three.

After these experiments were completed, which established the variation in the luminous intensity of incandescent lamps on alternating-current circuits, it was found that experiments had been performed at Columbia College* to determine the maximum frequency at which a noticeable flicker could be observed. The following extract is from the report of these experiments given before the A. I. E. E.:

> A number of years ago in the laboratory of Columbia College we had a small rotary converter which was under control so that we could produce alternating currents of any frequency we desired, and we made a good many tests with 15 to 20 students at a time, in order to determine what frequency could be detected. The condition is quite different from what it is to go where a system is being operated at 25 cycles. You know the frequency and you look at a lamp, and you say, yes; you can see the flickering of the light. But if you start with a high frequency and gradually lower it, telling everyone to keep his eyes on the lamp, different men will at different instants say that they detect a flicker; and if, as you repeat that experiment, the same man detects a flicker at the same frequency, that is pretty good proof that he does detect a flicker. Under other conditions there is a good deal of imagination about whether you detect the flicker or not. As a result of a good many experiments of that kind, with lamps at various efficiencies, we found that 20 or 21 was about as high a frequency as any man could detect repeatedly. In fact, the majority could not detect a frequency of 20.

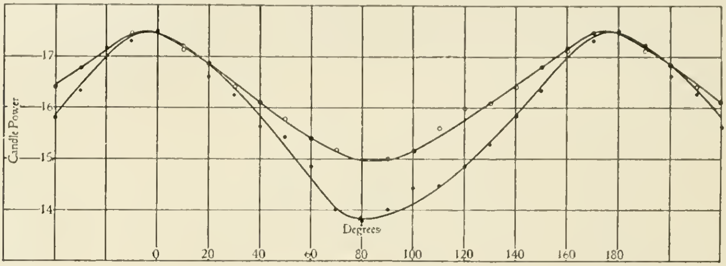

FIG. 2—CURVES OF CANDLE-POWER VARIATION OF A 3.1 AND A 4 WATT, 16 CANDLE-POWER, 100 VOLT, LAMP AT 25 CYCLES

●=3.1 watt lamp.
○=4 watt lamp.

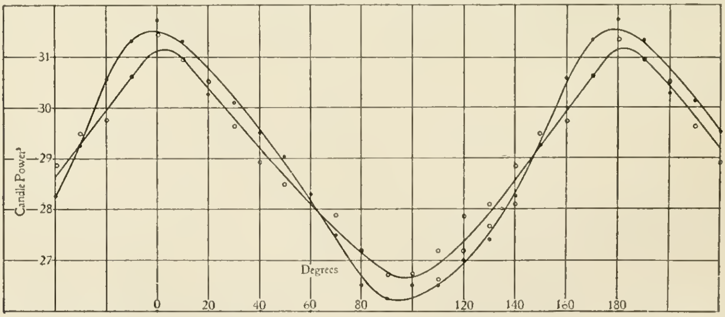

FIG. 3—CURVES OF CANDLE-POWER VARIATION OF A 3.1 AND A 4 WATT, 32 CANDLE-POWER, 100 VOLT LAMP AT 25 CYCLES

●=3.1 watt lamp.
○=4 watt lamp.

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*A. I. E. E., Vol. XXII, p. 383, 1903, Mr. H. A. Storrs.

Messrs P. Janet and G. Leonard had pursued the same line of investigation* that we had, but further than the crude apparatus in our possession permitted. Their results are interesting for comparison and also for suggestion.

Attention is called to the fundamental formula which forms a basis of Mr. Janet's mathematical treatment:

> The power delivered to an incandescant lamp, $P = \frac{{}_2\sin \omega t}{R}$
>
> The term denoting the wave form enters as a square into this expression, which would magnify any irregularity in the wave shape. Therefore it is to be expected that a peaked wave would produce a flickering light at the same frequency that a pure sine wave would produce a steady light, due to the greater difference of maximum potential. The variation in the angular velocity of the prime mover, as in the case with slow speed reciprocating engines with sluggish governors, or interchange of current between the generators or surging on the system produced by synchronous apparatus would cause a decided flicker which would not be noticed on a system with closely regulating engines or turbo-generators which have little if any variation in angular velocity. The periodic variation thus set up when combined with the normal wave may result in a variation of sufficient magnitude to make the lamps flicker.

The last paragraph quoted from the work of Messrs. Janet and Leonard sets forth the fact that the wave form influences the amount of variation of luminous intensity. This is in accordance with the fundamental formulae for power delivered to the lamp. It would be possible with a wave form of the proper shape to produce a light that would not flicker at any frequency.

The apparatus used by Messrs. Janet and Leonard was similar to that described above with the addition of attachments for determining the instantaneous values of current and electromotive force. The following is a summary of the results obtained:

> The curve of variations is periodic with time. The frequency is double that of the supplied power. The variations are not sinusoidal. The curve of luminous intensities lags behind the curve of difference of potential.
>
> The maxima of the curve of luminous intensities and of the difference of potential, are separated from each other by a fraction of a period smaller than are the minima.

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*For Janet's mathematical treatment see L' Eclairage Electrique, Vol. XI, page 507, and for his physical demonstration in connection with C. Leonard, see Bulletin de La Societe' Internationale des Electriciens Bulletin 1, page 615, December, 1901.

TABLE I. (See Fig. 4)

	Frequencies		
	30	42	55
Luminous intensity, maximum	15.3	15	14.65
" " minimum	12.75	12.85	12.9
Absolute variation	2.55	2.15	1.75
Relative variations, per 100	18.5	16	12.7
Mean lag of maximums	30	35	35
Mean lag of minimums	50	50	45

Upon inspection of the values of the preceding table it may be seen that:

1. The frequency of the variation of luminous intensity increases with that of the difference of potential of the supply.
2. The variation, absolute or relative, of the luminous intensity of the lamp diminishes when the frequency increases and inversely.
3. The curves tend to become sinusoidal when the frequency increases.
4. The difference in phase appears to remain constant from 30 to 55 cycles.

TABLE II. (See Fig. 4)

Lamp at 27 volts.

Standard on constant current, 15.4 candle power, 27 volts, 1.7 amperes, 46 watts, 3 watts per candle.

	Frequencies	
	42	15
Luminous intensity, maximum	16.1	14.65
Luminous intensity, minimum	16.43	13.4
Absolute variation	1.8	4.35
Relative variation, per 100	11.7	28
Mean lag of maximums	45	40
Mean lag of minimums	52.5	45

According to the preceding table the variation of luminous intensity increases when the frequency decreases, as from 11.7 per cent. to 28 per cent. for a variation of frequency from 42 to 15.

In the lamp of lower voltage the angle between the maximum and minimum of the curve of luminous intensities and of the difference of potential decreases with the frequency.

TABLE III. (See Fig. 4)

Lamp at 27 volts.

Standard on constant current 53.5 candle power, 20 volts, 5.6 amperes, 112 watts, 2.1 watts per candle.

	Frequencies		
	42	20	10
Luminous intensity, maximum	54	56.3	57.6
Luminous intensity, minimum	50	49	44.8
Luminous intensity, mean	52.5	52.5	50
Absolute variation	4	7.3	12.8
Relative variation, per 100	7.6	13.9	25.6
Angle between the maximums	45	60	25.6
Angle between the minimums	60	70	——

The relative variation increases from 7.6 per cent. to 25.6 per cent. when the frequency decreases from 42 to 10 periods. At this last frequency the measurements were difficult to obtain with accuracy because of the variations of illumination produced on the photometer screen by the slow rotating speed of the disc.

In the above table the angle appears to increase when the frequency decreases, but this result is doubtless due to experimental error.

Variation of candle-power with frequency.

We have plotted on the abscissa lengths proportioned to the frequency and on the ordinate values proportioned to the luminous intensities, maximum and minimum. (See Fig. 4.) Table 1 gives us the values of maximum and minimum luminous intensities, at frequencies of 30, 42 and 55.

From Fig. 4 it may be seen:

1. That the two curves of luminous intensity, maximum and minimum, tend to meet towards the infinite frequency.

2. That the absolute variation of luminous intensity varies rapidly at low frequencies and very little above 50 periods.

3. The maximum variation of luminous intensity increases more rapidly than the minimum.

4. The curve representing the variation of luminous intensity of the lamp has for asymptote the axis of frequency.

Influence of the mass of the filament upon the variations of luminous intensity of a lamp at incandescence in one period.

The energy dissipated in heat and light by the filament of a lamp at incandescence is proportioned to its radiating surface, the temperature and emittive power of the filament remaining constant. At a constant temperature its calorific capacity is proportional to its mass. The energy dissipated by the filament of an incandescent lamp of constant length increases with the radius, while the calorific capacity increases with the square of the radius. If for the same power dissipated the radius of the filament is increased, results obtained with low voltage lamps, the relative variations of power furnished to the filament during half a period, is less than the total energy stored in the filament and as a consequence variations in luminous intensity.

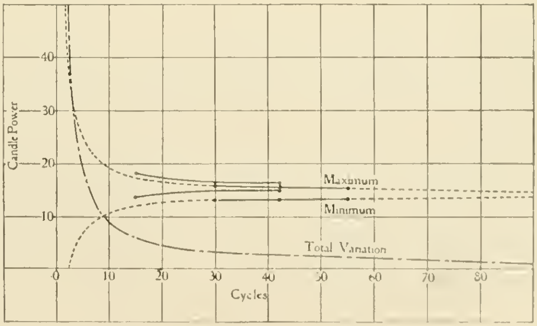

Fig 4—CURVES SHOWING VARIATION IN CANDLE-POWER WITH THE FREQUENCY, OF LUMINOUS INTENSITY, MAXIMUM AND MINIMUM, OF A 110 VOLT, 13.8 CANDLE-POWER LAMP.

The following table gives the variations determined on several lamps at a difference of potential of the supply and filaments of different masses, at a frequency of 42.

TABLE IV.

Lamp Numbers	1	2	3	4
Difference of effective potential	110	110	27	20
Mean luminous intensity, alternating current	15.6	13.7	15.4	52.5
Watts per candle	2.9	4.2	3	2.1
Luminous intensity, maximum	16.9	15	16.1	54
Luminous intensity, minimum	14.1	12.85	14.3	50
Variation, absolute	2.8	2.15	1.8	4
Variation, relative, per 100	18	16	11.7	7.3
Angle between the maximum	45	40	45	45
Angle between the minimum	50	50	52	60

We have deduced from the curves of Fig. 4 the variations of luminous intensity, of lamps 2 and 3 at a frequency of 20 periods.

Lamp Numbers	2	3	4
Absolute variation of luminous intensity	3.9	3.5	7.3
Relative variation per 100	28.5	22.5	13.9

The variation of luminous intensity at the same frequency diminished when the difference of potential diminishes, or when the mass of the filament increases; we suppose the difference of potential is a function of each and corresponds to about the same number of watts per candle, the luminous intensity being measured in a plane perpendicular to that of the filament.

The angle between the maximum and minimum of luminous intensity and the maximum and minimum of potential difference varies very little with the mass of the filament.

Influence of the wave form of the e.m.f. on the absolute variation of the luminous intensity of an incandescent lamp.

In the preceding paragraphs we have considered the potential curve as almost simusoidal. If the potential wave form was rectangular there would be no variation in the illumination of the incandescent lamp for whatever frequency employed.

If the potential curves of the supply has the form of a trapezium, of a sinusoid or of a triangle, the variations of luminous intensity increase at a constant frequency and the maximum will be for the triangular wave shape.

One might say that the absolute variation, during a period, of luminous intensity of a lamp at incandescence increases with the ratio of the maximum potential to the effective potential.

LIGHTING ON 25 CYCLES IN BUFFALO

H. B. ALVERSON

Superintendent, The Cataract Power and Conduit Company, Buffalo, N. Y.

THE use of 25 cycle current for lighting purposes in Buffalo dates from the autumn of 1897, when alternating current of that frequency transmitted from Niagara Falls was offered for general commercial power purposes. The electric power transmitted for a year previous to that date had been used only for street railway supply, being transformed for that purpose then as it is to-day to direct current by means of rotary converters.

The use of 25 cycle current in lighting has kept pace with the installation of the electric motor drive in the various industrial plants, and but six of these have found it desirable to transform to direct current and make use of arc lights. Not one, save the local lighting company, which furnishes the house, store and public street lighting of the city, has found it necessary to transform to some other frequency, and that one has done so in most cases because of conditions previously existing.

Incandescent lamps naturally form the bulk of the lighting, and it is customary to use them on circuits taken directly from the power transformers whenever power service is installed, although a trifle better result in the matter of regulation is obtained when separate lighting transformers are maintained. This applies more particularly to the case of overloaded power transformers on inductive load. On but one circuit in the entire city is a voltage regulator used, and that is a power circuit which is very heavily loaded at certain times.

Much has been written and discussed as to the flickering of incandescent lamps on a frequency of 25 cycles. It is an extremely difficult matter to detect any variation of light on the Buffalo circuits due to that cause. The excellent Niagara wave form or the fact that it has passed through four sets of transformers between the generator at Niagara and the consumers' lamps in Buffalo may have something to do with it, although the writer is unable to detect any difference at the two places. Much of the discussion of this feature of the 25 cycle lighting has arisen from other causes than the periodicity; such as the testing of small units not designed for the purpose driven by prime movers of poor regulation, belt slippage, low voltage of lamps under test and mechanical vibration of lamp filaments. The mechanical vibration of lamp filaments on 25 cycles is a trifle more prevalent than on a higher periodicity and is usually mistaken as a slight variation due to the frequency. This mechanical vibration is present in but a comparatively small proportion of the lamps, and may be removed by any one of a number of means—such as by altering the position of the lamp in the socket so as to change the plane of the filament, by substituting another lamp of the same wattage having a stiffer filament, by replacing with a lamp of greater watts per candle, or by changing to an anchored filament lamp.

That any variation in 25 cycle lighting here is difficult to detect is evidenced by the following incident: We were favored with a call several years ago by the superintendent of the lighting company of a city of about the same size as Buffalo, who was interested in the subject of this article. On the way to witnesss this lighting he stated in a very non-egotistical manner that he prided himself on his ability to distinguish the nature of the current, direct or alternating, on which a lamp might be installed. He was asked at what hotel he was lodging, and on replying was informed, to his amazement, that the entire lighting of that place where he had been for two days, was served by a 25 cycle circuit.

On the circuits of power customers the lamps are largely four watts per candle, for the reason that they were advised to so purchase, with the idea that these lamps would give better satisfaction under possible voltage variations. Where lights are on separate circuits, such as those of the local lighting company, three and one-half watt lamps are used, and give as good service as on a higher frequency. Lamps worked under normal voltage show a true flickering due to frequency, but when this does occur, the illumination would be equally poor with the same conditions at a higher frequency. Lamps are used on any voltage from 90 to 250, and no difference due to the frequency can be detected. About one-third of the lights are on voltages of 200 and upward. Metallized filament lamps work as well on this frequency as do the other incandescent lamps. No exact life or efficiency measurements have ever been made here on incandescent lamps of various voltages and wattages with a view to finding out the most economical lamp, but our best judgment would indicate that within the limits above mentioned as to consumption of current and voltage, their performance is not far different from lamps on more common frequencies.

The use of automatic arc lamps on 25 cycles up to date has proven a failure except in an extremely narrow application, which has never been used in Buffalo. This is due to the flickering resultant upon the alternate heating and cooling of the arc. This seems to be the one application where 25 cycle current falls down. Hand feed arc lamps operate finely and are used in a half dozen schools for lantern projection purposes. Of the six customers previously mentioned who transform 25 cycle current to direct current for use in arc lamps, all operate foundries and use them solely about the works, while using the 25 cycle lamps about their offices. Three of these foundries, operating 95 per cent. of the arcs, used them previously to the substitution of 25 cycle current for steam power. The use of arc lamps in connection with the mercury vapor rectifier seems to offer a solution of this question, although this has never been tried in Buffalo. The mercury rectifier on 25 cycles is used with absolutely satisfactory results on battery charging, although as a light only, its flickering is similar to that of the carbon arc.

It was hoped that Nernst lamps would take the place of arcs on 25 cycles, but to date they have not proved to be as efficient and reliable as on 60 cycles. However there is one large foundry operating 48 6-glower, 80 3-glower and 24 1-glower Nernst lights with results that compare with arc lighting, principally due to the fact that careful and intelligent attention is given to them. One of the conditions where this form of light has been found especially applicable is in the illumination of the beautiful Albright Art Gallery. A majority of the pictures viewed by it look much more natural than by cloudy daylight, and the result produced approaches a sunlight effect.

There are at present in Buffalo over 50 000 16-c. p. equivalents connected on 25 cycle circuits. About one-half of these are on the power circuits of The Cataract Power & Conduit Company, with over 3 000 16-c. p. equivalents in Nernst lights, while the balance are on the circuits of the Buffalo General Electric Company, a customer of the former. The circuits of the lighting company have no voltage regulation on them, and run in the principal residence district of the city. Among its cutomers are three of the leading clubs, two of the large hotels, a reference library, the before-mentioned art gallery, the 74th Regiment Armory and numerous stores.

A comparison between 25 cycle and 60 cycle distribution works out about as follows: Given the case of an 11 000 volt 25 cycle supply available, what would be the most economical investment for a central station to distribute to its customers?. If the distributing circuits are to be at 2 200 volts, there is necessary in the 25 cycle case, step-down transformers only at the sub-station, while in the 60 cycle case a motor-generator outfit is necessary in addition. For our present discussion we will omit the extra value of floor space, the higher class of attendance, extra switchboard, extra maintainance and liability to trouble in favor of the 25 cycle outfit. On the outside circuit at the customers' we will assume that there is a transformer capacity in both cases equal to the generating capacity in the substation. The difference in investment will then be as ten to six in favor of the 25 cycle circuit. Should the transformer capacity on the outside circuit be double the generator or transformer capacity in the substation, the investment will be as ten to eight again in favor of the lower frequency. The approaching towards equality of investment being due to the greater cost of the 25 cycle transformers over 60 cycles in the small sizes of one kw, two kw and three kw, which have been used in comparison, the difference in cost in favor of the 60 cycle being about 20 per cent., though this does not hold in the larger sizes of transformers.

Naturally, 25 cycle lighting is used at Niagara Falls by all the power customers of the Niagara Falls Power Company, including the village of Echota. The local lighting company at Niagara Falls uses 25 cycle lighting extensively, and reports that their customers were unaware of the change from 125 cycles to 25.

The Manhattan division of the Interborough Railway Company in New York uses about 30 000 16-c. p. equivalents in the lighting of shops and stations, all on 25 cycles.

The entire illumination of the Pan American Exposition was done at 25 cycles, about 200 000 8-c. p. equivalents being so used.

Summming up, 25 cycle illumination in Buffalo has proved equal in value to any other form of electric illumination, save that of its use for arc lights, and in the latter case the difficulty has been easily met.

VARNISHED CLOTH CABLES FOR POWER HOUSES AND DISTRIBUTING STATIONS

HENRY W. FISHER
Chief Engineer, Standard Underground Cable Company

IN many ways varnished cloth cables are especially suitable for high voltage service in power houses. There is, however, a great difference in the electrical qualities of various kinds of insulating varnishes and varnished cloths so that, for high voltages especially, the greatest care must be exercised in the selection of the right kind of varnished cloth.

Imperfect or unsuitable material becomes warm under the continued application of a voltage over fifty per cent. of the maximum voltage the material will withstand for a minute. The writer has made comparison tests between cables insulated with different kinds of varnished cloth and having the same thickness of material, where some cables would be excessively hot and others almost cool to the hand at the end of one or two hours application of a high voltage.

After much experimenting a special black material was found which possessed qualities most desirable for high voltage cables and those herein mentioned were insulated with this black varnished cloth which in every way tested was superior to any of the yellow varnished cloths. Many of the yellow varnishes contain linseed oil which seems to be objectionable in the insulation of cables for high voltages.

Varnished cloth cables with flameproof or asbestos braids seem eminently fitted for high voltage wiring in power houses. Such cables placed on insulators reduce to a minimum the possibility of fatal shocks to a workman who accidentally touches the wires.

A prominent electrical engineer recently wrote for a sample of 250 000 circ. mil. cable for 60 000 volt service such as could be placed on insulators in a distributing station. It was expressly stated that sufficient insulation should be applied so that there would be no danger of loss of life to a workman who accidentally touched the cables when in service. An insulation of twelve-thirty-seconds of an inch of varnished cloth with flameproof or asbestos braids was recommended. Samples of both kinds of cables were submitted for tests. They were first placed on insulators and tested with a gradually increasing voltage until the e.m.f. was 90 000 volts when there was a slight indication of static discharges around the insulators. At 60 000 volts there was no perceptible noise nor visible sign of static discharges around the insulators. Finally, two or three feet of the samples were submerged in water and a test was made between the conductors and water. The applied voltage was gradually increased until the insulation broke down, which occurred between 115 000 and 118 000 volts. These tests were very satisfactory to the electrical engineer and accordingly cables similar to the sample having the asbestos braid were installed.

Varnished cloth cables which have to be laid in damp ducts should be supplied with a lead cover; hence, for outdoor conduit work, they are no better than paper insulated cables. It is questionable whether non-leaded varnished cloth cables for high voltages should be laid in ducts underneath the floors of power houses. If the braids become very damp, there would be a tendency for the charging current to flow along the braid of one conductor to the point of least resistance and thence to the other conductor. This might cause the cables to become very warm in spots and eventually burn out. For similar reasons, under certain conditions, there might be danger of a severe shock to a person touching one of the cables.

It is not advisable to subject varnished cloth cables to one-half hour time tests of voltages over one-half the puncture test voltage of the cables. They can, however, be subjected to one minute voltage tests of three-fourths the puncture test voltage.

Looking at this from another standpoint, it may be stated that a well designed varnished cloth cable can be subjected to a one-half hour test of double the working voltage and to an instantaneous voltage test of three times the working voltage. Varnished cloth cables seem to have the property of withstanding comparatively high instantaneous rises of voltage such as occur at the time of surges, and hence there is no necessity of subjecting them to prolonged tests of two and one-half or three times the working voltage, which would have a tendency to overheat the insulation. Cables made with proper varnished cloth do not become warm from dielectric losses when tested with the normal working voltage continuously.

EFFECT OF STEAM AND SMOKE ON STRIKING DISTANCE

S. M. KINTNER

IT has been suggested that where high voltage trolley wires are placed over the tracks of railroads using steam locomotives, and particularly at such places as tunnels and points where the trolley lowers under bridges, there might be electrical discharges from the trolley to the locomotives and ground through the steam and smoke of passing locomotives. To determine the likelihood of such an occurrence the following tests were planned and carried out:

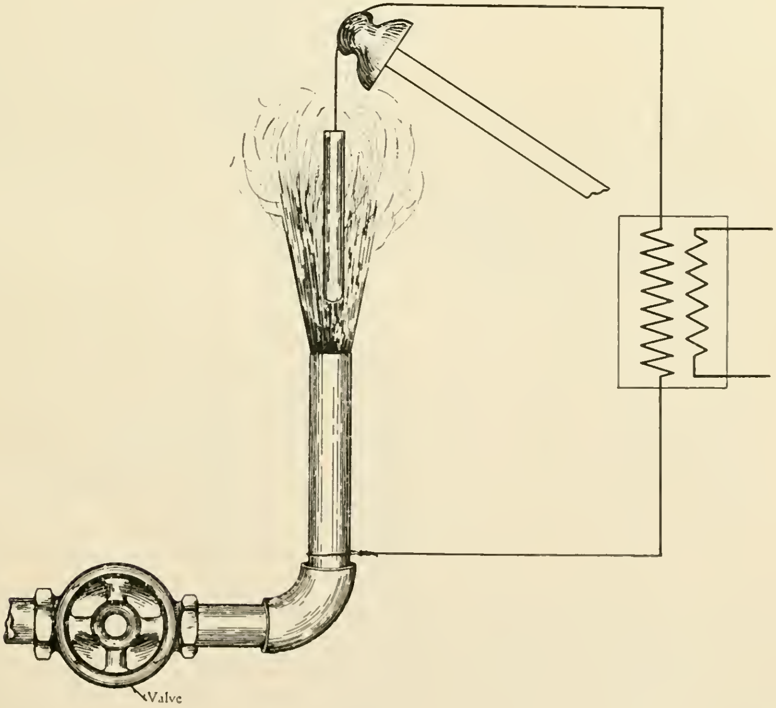

FIG. I

Two terminals were placed, one above the other, and arranged so that the space between them forming the discharge gap could be varied at will. The terminals were one-half inch in diameter with spherical ends and were so mounted that jets of steam and smoke could be projected around the terminals in a direction parallel to their axis of support. The arrangement of the terminals with relation to the steam can be seen in Fig. 1. In the first test a column of steam was projected across the gap as shown. The steam was purposely made very moist by passing it through a long line of pipe so that it lost a large quantity of heat before arriving at the gap.

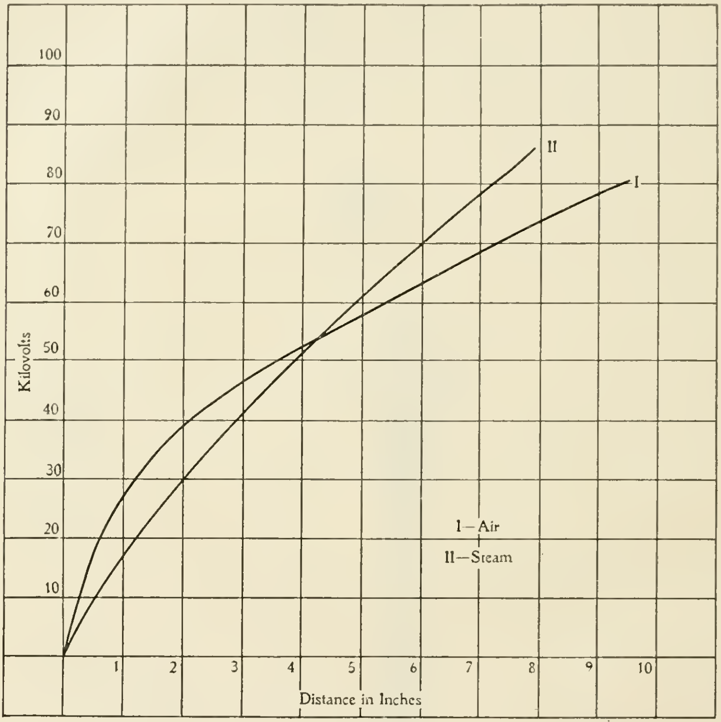

FIG. 2

The results of this test are shown in the accompanying curves, Fig. 2. From these curves it can be seen that the striking distance is greater for a given voltage in air for voltages below approximately 55 000, but that at this point the curves cross each other and it requires a greater voltage to jump a given gap in steam than in dry air. The jumping distance in air as plotted in this curve was obtained by measurements taken at the time the curve for steam was determined, the same terminals being used, and the points checked several times, so that it seems certain that the values are relatively correct. During the test with steam, the terminals were saturated with moisture, and water dripping off them freely. No perceptible change was noted, however, when the steam was somewhat drier.

The next test was made when the terminals were immersed in a dense volume of smoke. This smoke was produced by building an intense fire in a small stove. After a very good bed of coals was obtained, some fresh coal containing more or less dirt, sulphur, etc., was thrown on to prevent perfect combustion and produce large quantities of very dense black smoke. Fig. 3. shows the arrangement of the stove, steam line, spark gap, etc. It was in this case impossible to maintain constant conditions long enough to run a curve but a number of observations were taken, which indicated that the striking distance was not materially reduced from that of the steam or air in the previous test. One set of the readings is given in the following table on the next page.

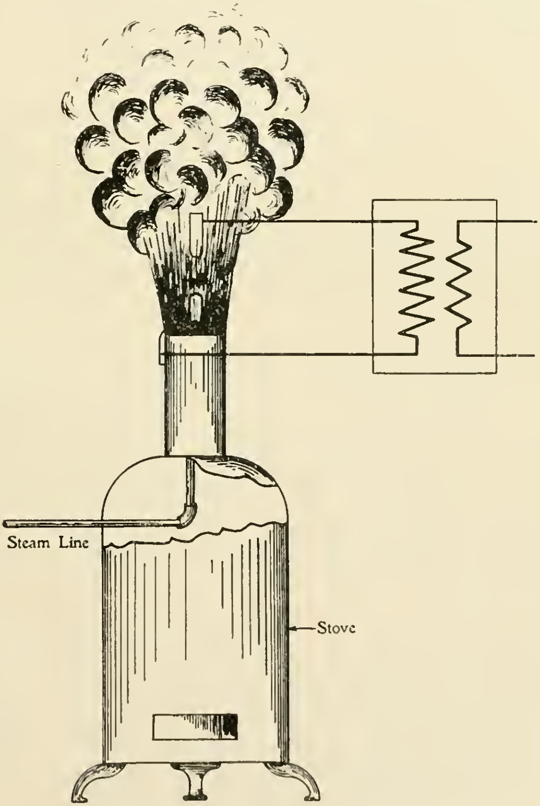

FIG. 3

TABLE OF VOLTAGE-STRIKING DISTANCES IN DENSE SMOKE AND STEAM

Voltage.	Distance in inches.
14 000	1.375
25 000	2
35 000	3
42 000	3.75

From the results of these tests it seems fair to conclude, that with a reasonable factor of safety over the dielectric strength of air, of possibly six or seven, no difficulty will be encountered from the presence in the air of steam and smoke.

ROAD EXPERIENCE

F. C. VEHSLAGE

SOMETIMES a short-circuit will occur in the armature of a solid frame railway motor in such a place as to burn the band wires, thus allowing the coils to fly out and occasionally wedging the armature so that it will not revolve in either direction.

In my experience this has occurred twice. The first time the car was near a siding, and it was possible to get it off the main line by sliding the locked wheels, thereby causing two very bad flats. The pinion could not be removed because it was too close to the wheel. The gear could not be removed because the wheel would not revolve. So it was necessary to carry to the spot a new motor and such tools as were needed and put in the new motor on the siding.

Some time later the same trouble occurred with another motor at a spot on the road not so convenient to a siding. This time the bottom gear-case was taken off, (the top gear-case could not be removed because the body of the car was too low), the axle caps and axle bearings removed, and then by the use of a five by five inch timber, eight or ten feet long for a lever, with a rail for a fulcrum and with a short piece of wood about fifteen inches long on the end of the lever under the gear-case arm of the motor, the motor was lifted four inches above the axle, and a four by four inch well greased hardwood block was put in between the motor and the axle. This allowed the pinion to clear the gear by one-half an inch, then by raising the top gear case two inches and securing it in that position, the car was run to the repair shop. With two men equipped with proper socket wrenches, the time required to do the work after arriving at the scene was twenty minutes.

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Electric Wagons

The variety of electrical, mechanical, operative, commercial and financial considerations which enter into a single enterprise, likewise the wide chasm which lies between an electrical invention and its ultimate utilization are clearly illustrated in the article dealing with the electric power wagon in this issue of the JOURNAL. The vicissitudes which the electric automobile has encountered in adapting itself to successful commercial operation are set forth by one who has for many years been closely connected with the development and introduction of this class of apparatus.

Mr. Eames points out several of the reasons why failure has followed some of the cases where electrical operation by local transportation companies has been tried. It will be noted that usually the causes have not been fundamental, but have been susceptible to ready remedy. It is not unreasonable to suppose that a storage battery should receive a supervision and care which is at least as intelligent and as familiar with its characteristics and needs as is the care which is given to horses, although if horses received no better care than certain batteries they would live no longer than the batteries.

The principal introduction of the automobile has been for pleasure purposes. Its introduction for commercial purposes, either for light delivery wagons or for heavy trucks, naturally meets with greater conservatism and closer inspection of costs. There are, however, many economic advantages in the use of mechanical over horse-power which are sure to win out. The greater carrying capacity and quicker delivery, accompanied by reduced running expenses, all insure the ultimate general adoption of this new method. When bigger loads can be carried farther and faster by means of motor-trucks than by the most powerful teams, it means that the horse-truck, as well as the horse-car, has seen its best days.

An important feature of electric vehicle development lies in its relation to the central station. One of the foremost problems in central station management is the development of a market for power at the times of ordinarily light load. The additional cost to a central station for producing power after the peak load of the evening until morning and usually until the following evening is relatively small. The charging of vehicle batteries during these hours appears to be a most promising means for increasing the load factor and the dividends of ordinary central stations.

CHAS. F. SCOTT

Accidents in Power House Operation

We often hear of accidents that occur to the operators or apparatus in central stations. We are naturally more or less interested in knowing the cause or reason for these accidents. Investigation has shown that about ninety per cent. of the accidents are caused by carelessness on the part of the operator or an assistant. Many ingenious devices have been designed to overcome carelessness on the part of operators, such as interlocks, telltales, and so forth.

It is the intention of the designing engineer to make power house apparatus as fool-proof as possible. Yet with as many safeguards as can be thought of operators sooner or later become careless and accidents are generally the result, often causing severe strains to be thrown on apparatus, which sometimes lead to serious trouble.

In a certain power house the generators were connected to water wheels, and in order to bring the generators to a stop it was the custom of the operator to short-circuit the terminals by means of a piece of cable after the water valves had been closed. This was done because the valves leaked enough to keep the water wheels turning, but after being brought to a stop the leakage pressure was not enough to start them. The operator in this instance, through carelessness or forgetfulness, short-circuited a unit that was running at full voltage, and which was "cut in" on the bus bars. This unhappily resulted in the loss of the attendant's life as well as causing a considerable amount of damage to the electrical apparatus throughout the station.

There have also been a number of cases in which trouble has resulted because the operator took some one's word that things were all right. This is a bad policy, and if possible everything should be checked over when any undertaking is in hand. When new apparatus is installed and is about to be started those who have been assisting in the work will often state positively that all connections have been properly made. In many cases this has proven to be incorrect and the result in some instances has been loss of time and suspension of service together with a severe strain on the apparatus.

Lack of technical knowledge has been a considerable drawback to many operators. Operators who have started in as oilers and have then been promoted to electrical attendants have been taught and have also learned by observation that by closing certain switches they could obtain certain results. As long as everything runs smoothly such men are very satisfactory attendants. But if something out of the usual takes place they are in most cases helpless and often cause additional trouble by mistakes they make while attempting to correct trouble.

There was one case in which the installation of some 250 kw. 60 cycle generators direct-connected to water wheels was left to a man who claimed that he was well versed in this class of work. The machines were stored in the power house and subjected to more or less moisture. After being erected and started up they could apparently be raised to only half voltage. A load was thrown on, however, and an attempt made to raise the voltage by speeding up the water wheel. Then the insulation broke down between phases, resulting in the burning out of one-third of the winding.

The second machine was put through the same operation, and the instrument transformer burned out. This put an end to the experiments until the company manufacturing the apparatus could be communicated with. Investigation showed that the transformer voltmeter was connected up for the wrong ratio and the voltmeter was reading only one-half of the true voltage of the generator.

An amusing incident which will illustrate the lack of knowledge on the part of an operator, and also give an idea of the class of men sometimes found handling electrical apparatus, occurred a short time ago. Several sub-stations containing oil-cooled transformers were installed in connection with a high tension transmission line. One of the operators who had just been placed in charge of one of these substations called up the erecting engineer and requested that he come at once to the sub-station and remove some frogs that had gotten into the transformers. Upon being asked how he knew there were frogs in the transformers, he innocently replied that anybody who knew anything at all could tell by the bubbles coming to the surface of the oil.

Such are the men to whose tender mercies power house apparatus is sometimes intrusted. But it is through carelessness rather than ignorance that troubles usually come. Intelligent care and common sense are the elements most needed in the handling of electrical machinery.

H. Gilliam

> *"I have all my life been innocent of any other system than that of doing with all my might whatever task is given me to do. When I have made plans, they have usually been set to one side, and I have been set to other tasks. I have not sufficient confidence either in my own judgment or in my capacity to foresee the circumstances of future years. In a general sort of a way I have a notion that the line of action lies in a certain direction, and I work with my face turned thitherward. But at any moment I may be harnessed to a task which I did not foresee, which if I had foreseen I would have tried to evade, but which, nevertheless, was obviously the only thing to be done when the time came."*

W. T. Stead, "the most famous editor in the world, a publicist with perhaps greater influence than any other private individual, an organizer of world-wide movements, a man who gets results," uses these words in a significant article entitled "My System: Get The Thing Done," in *System* for April, 1906.

Apprenticeship as an Investment for the Future

The electrical engineer cannot foresee the circumstances of future years, nor block out a definite career for himself. The changes which are taking place so constantly in the electrical field are continuously imposing new duties upon the men engaged in electrical affairs. The increasing applications of electricity, the improved methods, the new objects to be obtained, and the larger and larger scale upon which electrical enterprises are projected and carried out have made a history of continuous development in the past, which shows no indication of abating in the future.

To be up-to-date, men must be prepared to do things which are different from what they have done before, and often to do things which have never been done before. Hence, the young man who is preparing himself for an electrical career is wise if he lays a broad foundation. His theoretical training is narrow if it acquaints him only with a few facts and laws, and the construction and operation of a few types of apparatus. It is narrow if it deals only with purely theoretical and purely electrical subjects. The true purpose of an education is development; it is to equip a man with the ability to do things and to train him in using himself.

The value to a college graduate of a subsequent practical training and experience is likewise generally recognized. The apprenticeship courses, which large manufacturing companies offer, give an excellent opportunity for obtaining such experience. One of the strongest arguments for the value of such training is the fact that such courses have been established. These companies have found that this is the best means of producing good men. There is nothing sentimental about these apprenticeship courses. They would never have been established if the companies had found that the men who came to them from the colleges could take up their work advantageously without this experience.

The apprenticeship course, however, has a broader significance to the young man than the mere preparation for an immediate position. It affords opportunity for acquiring an intimate knowledge of many of the fundamentals in electrical work, which give a broad foundation for the future. What the future may have in store for the designer, for the commercial engineer, for the consulting engineer, for the station superintendent, or for the manager of electrical properties cannot be foreseen, nor can a young man surely determine in what succession of relationships his future career may lie. Hence the importance of a training and experience which will be a useful basis in almost any kind of work upon which he may enter. It is his capital; it may be used in many ways; it may bring large returns.

Chas. F. Scott

Graphic Recording Meters

The new graphic recording meter, described and illustrated in this issue, covers broadly a complete line of direct-current and alternating-current meters, all operating in a novel manner.

The great drawbacks to most of the graphic meters heretofore designed have been:

1. The attention required every day in winding the clock, changing the paper or filling the pen.

2. An appreciable difference in the readings occasioned by the friction of the pen.

3. The increased power necessary to reduce the effect of friction. This power in the alternating-current meters is drawn from the series or voltage transformers, and thus causes inaccuracy or necessitates larger or more expensive transformers: in both alternating-current and direct-current meters the operating coils had to be designed to give high torque rather than high accuracy.

4. There were no means of varying the sensitiveness and speed of the pen motion in following variations.

The aim has been to produce an instrument which could remain in circuit and keep an accurate record for a considerable time without attention and to overcome the short comings of previous types. The "relay" principle was adopted as offering the best solution of the problem. According to this arrangement the "meter element" merely operates a set of contacts and thus the torque and the energy consumed in these coils need not be greater than in an indicating meter, and thus these instruments can be connected to series or shunt transformers already installed for other instruments without impairing the accuracy.

By means of an auxiliary circuit other than that of the secondary of the current or voltage transformers, the contacts operate a pair of solenoids connected to a parallel motion mechanism which moves the pen. This auxiliary current is preferably a 110 volt direct-current circuit, although good results may be obtained from other auxiliary circuits if this is not available. This circuit, not being derived from the meter transformers, may be of sufficient power to overcome all friction. The contacts and their circuits are so designed that sparking at the contacts is entirely obviated.

A new form of glass pen has been designed, in which the ink is fed into the marking point from a reservoir in which the ink is maintained by atmospheric pressure.

In modern operation there should be the same grade of excellence in graphic meters as has recently obtained in indicating and integrating instruments; this is now secured by the use of the "relay" principle. PAUL MACGAHAN

ELECTRIC RAILWAY ENGINEERING

CALCULATION OF SPEED-TIME AND POWER CURVES*

F. E. WYNNE

IN the selection of a motor for a given service there are a number of things to be considered. It is of primary importance that a motor should be chosen which is capable of giving the required service without becoming overheated. The amount of heating in service is determined by the square root of the mean square motor current and the average voltage on the motor. Again, the motor should be able to make the desired schedule speed safely and in addition it should have a reasonable margin in capacity and speed for making up lost time. At the same time, the maximum attainable speed should be kept as low as may be consistent with the above condition, and the gear ratio should be such that when the car is running at its maximum speed, the motor armature speed will not exceed a safe limit.

The characteristic curves of a motor show its performance for any given load at normal voltage. On a car, the motor is operating under a constantly varying load and the problem in any specific case is to find what its performance will be under such circumstances. The most important step in this problem is to determine the speed-time and power curves.

In starting a direct-current motor, resistance is placed in series with it so that a comparatively low voltage is applied to the motor at first. The resistance is gradually cut out by the operation of the controller until finally the full line voltage is impressed on the motor. It is possible to control the length of time consumed in this process and also the current and voltage supplied during this time. However, after the motor has the full line voltage applied to it, its performance is altogether dependent upon its characteristics.

With a series-parallel controller and suitable resistances a roughly uniform current of almost any desired value may be obtained during the time of starting by suitably operating the controller. The current obtained when the controller is first thrown on is dependent upon the resistance and the self-induction in the motor circuit. In any other position, it also depends upon the rapidity with which the controller is operated, the average value of the current during starting, decreasing as the time for operating the controller is extended.

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*This is the fourth of a series of articles on Electric Railway Engineering. The first article appeared in the January issue.

The rate at which a car is accelerated depends upon the torque developed by the motors. The torque depends upon the current and thus the rate of acceleration is dependent on the current. Hence the maximum allowable current is a determining factor in the rate of acceleration obtainable. The momentary current-carrying capacity is usually limited by the commutation. Another limitation to the rate of acceleration is found in the weight on the driving wheels. Under ordinary track conditions, if the tractive effort developed is more than one-fifth of this weight, the wheels will slip. The comfort of the passengers should be considered and the overload capacity of the power house and sub-stations should also be taken into account. Ordinarily cars are accelerated at rates between one-half and two miles per hour per second.

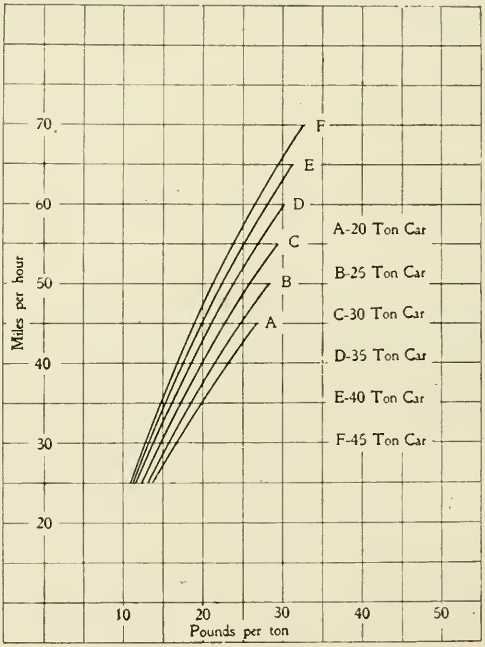

FIG. I—CURVES OF TRAIN RESISTANCE FOR SINGLE CARS

TRAIN RESISTANCE

Numerous empirical formulae have been developed for train resistance, some of them based on elaborate tests. The values obtained by the use of these various formulae differ widely. Certain tests indicate that for single cars, Blood's formula* is very close. The values derived from it are slightly higher than those obtained by actual measurement and are therefore on the safe side for use in theoretical calculations.

Fig. 1 shows curves made from this formula for cars of from 20 to 45 tons weight.

By assuming the following conditions, the speed-time curve for a 40-ton car equipped with 75 hp motors may be calculated.

Weight of car, including electrical equipment, brake apparatus and live load ....40 tons.
Track, straight and level
Train resistance as shown by Blood's formula, Fig. 1
Trolley e.m.f. ....500 volts
Length of run......................................1 mile
Length of stop.....................................10 seconds
Schedule speed.....................................24 miles per hour
Initial acceleration................................1.5 miles per hr. per sec.
Braking rate.......................................1.5 miles per hr. per sec.
Characteristic curves of motors are shown in Fig. 2.

A tractive effort of 100 lbs. per ton is needed to produce an acceleration of one mile per hour per second. Hence there must be $1.5 \times 100 \times 40 = 6\,000$ lbs. net tractive effort. The train resistance at 18 miles per hour is $9 \times 40 = 360$ lbs. The total tractive effort developed by the motors in starting must therefore be $6\,000 + 360 = 6\,360$ lbs. or 1 590 lbs. per motor. Referring to Fig. 2, it may be seen that the required tractive effort is produced when each motor is taking 134 amperes. At 500 volts, the speed corresponding to 134 amperes is 18 miles per hour. Hence the car may be accelerated at the rate of 1.5 miles per hour per second, until this speed is reached when the full line voltage is applied to each motor. The time required to come from rest up to the speed of 18 miles per hour when accelerating at the rate of 1.5 miles per hour per second is $\frac{18}{1.5} = 12$ seconds.

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*This formula is $R = A + BM + (C + \frac{D}{T})\, M^{1.8}$. Where R= train resistance in lbs. per ton, A=5.0, B=0.12, C=0.0014, D=0.35, M=miles per hour, and T=weight of car in tons.

Where not more than two trailers are handled by a motor car, the train resistance for trailers may be taken as

12 lbs. per ton from 0 to 50 miles per hour,
13 " " " " 50 " 60 " " "
14 " " " " 60 " 70 " " "

Consequently at the end of 12 seconds from the time the current is first thrown on, the car will have attained a speed of 18 miles per hour, the motors will be all in parallel and running on the motor curve at 500 volts. As the car speeds up beyond this point, the current decreases and therefore the tractive effort also decreases as may be seen from Fig. 2. Hence the rate of accelera-

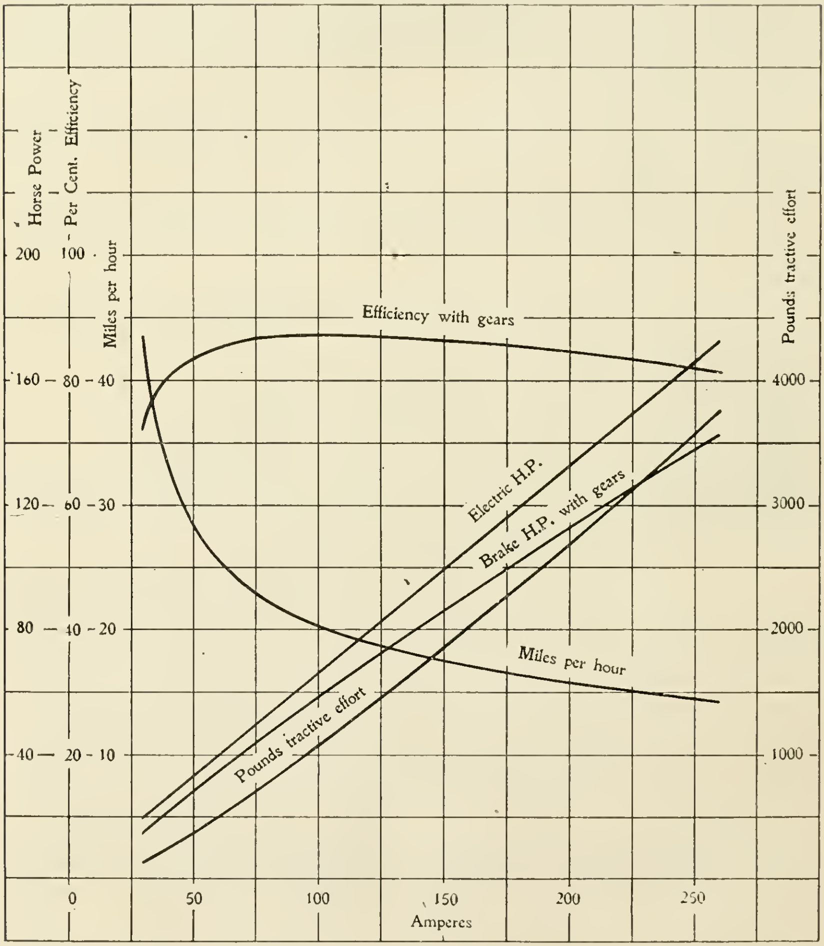

FIG. 2—PERFORMANCE CURVES FOR 75-HORSE POWER, 500-VOLT, RAILWAY MOTOR

tion can no longer remain constant but will decrease and the speed of the car will increase at a lessening rate. With increased speed, the train resistance is greater, which tends to still further reduce the rate of acceleration.

In determining other points on the speed-time curve, the process is as follows: Suppose the car has reached a speed of 19 miles per hour. The current will have fallen in value to 118 amperes and the tractive effort will then be 1 328 pounds per motor. The train resistance has increased to 93 pounds per motor. Hence at 19 miles per hour, the net tractive effort is $1\,328 - 93 = 1\,235$ pounds per motor and the rate of acceleration is 1.235 miles per hour per second. Since the tractive effort and acceleration have been decreasing gradually while the car was speeding up from 18 to 19 miles per hour, we may assume without serious error that the average acceleration* during this period is the average of the intial and final acceleration.

That is, the average acceleration between 18 and 19 miles per hour is $\frac{1.15 + 1.235}{2} = 1.367$ miles per hour per second. To increase in speed from 18 to 19 miles per hour—a difference of one mile per hour—at the rate of 1.367 miles per hour per second takes $\frac{1}{1.367} = 0.73$ seconds. Hence the car reaches a speed of 19 miles per hour in $12 + 0.73 = 12.73$ seconds from the start. This gives a point on the speed-time curve.

The speed will continue to increase beyond this point. At 20 miles per hour, the current is 103 amperes. The tractive effort is 1 100 pounds per motor, the train resistance is 96 pounds per motor and the net tractive effort is $1\,100 - 96 = 1\,004$ pounds per motor. Therefore the rate of acceleration at 20 miles per hour is 1.004 miles per hour per second and the average acceleration between 19 and 20 miles per hour is $\frac{1.235 + 1.004}{2} = 1.12$ miles per hour per second. The speed interval is one mile per hour and the time is $\frac{1}{1.12} = 0.9$ second approximately. The car will thus reach the speed of 20 miles per hour in $12.73 + 0.9 = 13.63$ seconds from the start and thus another point on the curve is known.

Other points may be found in the same way and the curve produced until it becomes a straight line at the speed where the tractive effort developed is equal to the train resistance.

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*This assumption is not strictly correct because of the varying rate of change of acceleration. However, by taking speed intervals of 3 miles per hour or less, the calculated curve will approximate the actual curve with a greater degree of accuracy than can be maintained in many of the subsequent calculations. Usually the error is less than one per cent.

In calculating and constructing a speed-time curve, it is most convenient to figure from the weight and tractive effort for a single motor. These figures are tabulated as below and the curve is plotted directly from the speed and time columns.

40-Ton Car. 4 Motors.

	Per Motor					
Miles per hour	Pounds tractive effort	Pounds train resistance	Pounds net tractive effort	Rate of acceleration miles in per hr. per sec.	Time in seconds	
18	1590	90	1500	1.5	12.0	
19	1328	93	1235	1.235	12.73	
20	1100	96	1004	1.004	13.63	
22	782	102	680	0.68	16.0	
24	605	110	495	0.495	19.4	
26	448	118	330	0.33	24.3	
28	365	125	240	0.24	31.3	
30	300	133	167	0.167	41.1	
32	251	141	110	0.11	55.6	
34	210	150	60	0.06	79.2	
36	190	160	30	0.03	124	
37.5	166	166	0	0	224	Ultimate speed

Fig. 3 shows this speed-time curve plotted from the above table.

When several curves are to be plotted for the same car with the same equipment, it is convenient to use an auxiliary curve sheet of the form shown in Fig. 4. A scale of pounds net tractive effort per motor is laid off to the right of the zero point and an equal scale is made to the left of the zero for train resistance. Scales of speed and acceleration are laid off on the vertical axis. The train resistance curve, *R R*, is then plotted. The tractive effort at any speed—say 20 miles per hour—is read from the motor curve. A pair of dividers is set for this value of tractive effort to scale and this distance is then laid off to the right from the train resistance curve at 20 miles per hour. This gives a point, *P*, on the speed curve. Other points are determined in like manner and the curve, *LS*, is drawn. Since the rate of acceleration is in all cases directly proportional to the net tractive effort, a straight line drawn through zero at the proper angle will give the curve between net tractive effort and acceleration for a single car on straight level track. For example, in Fig. 4, an acceleration of one mile per hour per second is produced by 1 000 pounds net tractive effort per motor. Hence a straight line through *OA* is the acceleration curve. From these curves the acceleration at any speed may be read direct. At the speed of 22 miles per hour, for instance, the net tractive effort is 680 pounds and at 680 pounds the acceleration is 0.68 miles per hour per second. From this it is seen that to obtain the acceleration at any speed it is only necessary to read from the acceleration curve the value on the vertical line through the speed point chosen.

The speed curve, Fig. 4, may be plotted from the point *L* which corresponds to the maximum current which the motor will commutate well to the point *S* which represents the limit of safe armature speed. The point *U* gives the ultimate speed which the car will reach on straight level track. The speeds between *U* and *S* may be attained on down grades.

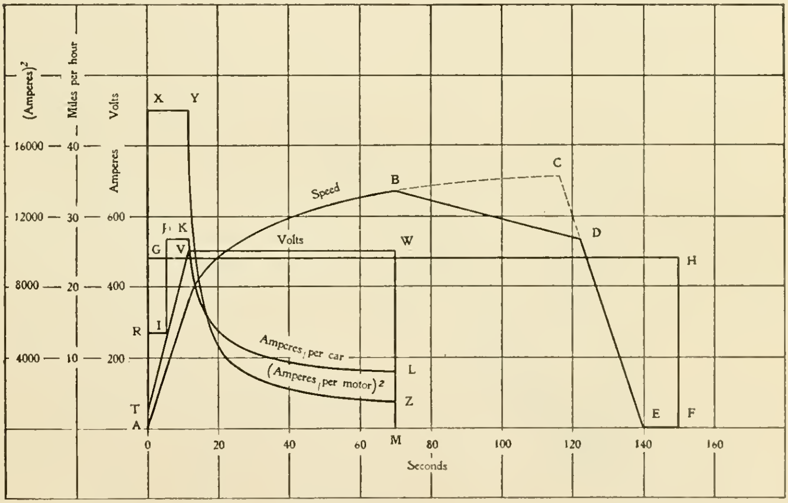


FIG. 3—SPEED-TIME AND POWER CURVES FOR 4-75-HORSE POWER, 500-VOLT MOTORS, 40-TON CAR, 1 MILE RUN, 24 MILES PER HR. SCHEDULE SPEED

If a car is starting up a grade it is equivalent to having the net tractive effort decreased by the amount of grade resistance. The same speed curve may be used but an additional line for acceleration on the grade must be drawn. To construct this line, lay off the distance *OG* equal to the grade resistance per motor and through *G* draw the line *BB′* parallel to *AA′*. A vertical line may be drawn through *G*, cutting the speed curve at *U′*, the ultimate speed which the car will reach when running up this grade. In a similar way, the acceleration line *CC′* may be constructed for the car running down the same grade and acceleration lines for other grades may be constructed. Acceleration lines for starting on curved track may be drawn in the same way.

If a 20-ton trailer is attached to the motor car, it is equivalent to adding a constant train resistance per motor of the amount *OT* = 60 pounds. A vertical line through *T* cutting the speed curve gives *V*, the ultimate speed which the car will reach when hauling the trailer on straight level track. The slope of the acceleration line will be as shown by *DD'*; for with the trailer 1 500 pounds net tractive effort per motor is required to accelerate the train at the rate of one mile per hour per second. This value must be laid off from *T* giving the point *E*, on the acceleration curve for the train. From the above description it will be seen that from such an auxiliary curve with a single speed curve the necessary values of acceleration for constructing speed-time curves under all conditions are easily obtained by the addition of a few straight lines.

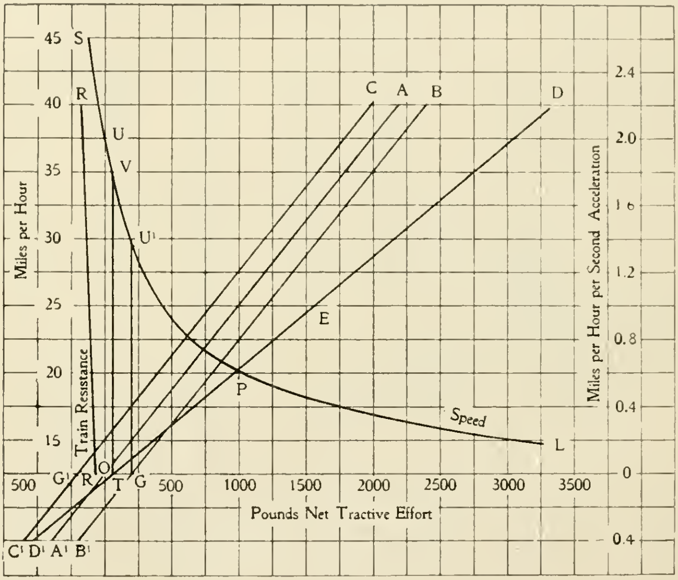


FIG. 4—CURVES SHOWING TRAIN RESISTANCE, SPEED AND ACCELERATION

The speed-time curve as calculated by either of the foregoing methods shows the performance of the car while the motors are developing power. In order to stop at a given point, the power is cut off and the brakes applied. After the power is off, the momentum of the car tends to keep it in motion and the train resistance tends to stop it. There is thus a force—the amount of the train resistance—producing negative acceleration. In the above case at 34 miles per hour, the train resistance is 150 pounds per motor and the negative acceleration is $\frac{150}{1000} = 0.15$ miles per hour second, that is, ten seconds after power is cut off the speed of the car will have been reduced 1.5 miles per hour. This gives the coasting or drifting line. The above determination of the coasting line is not entirely accurate because the train resistance does not include the friction and windage of the motors themselves. This motor friction does not have to be considered in working from the motor curve because this curve shows the tractive effort exerted at the wheel tread and does not include that used in overcoming the motor friction. Also since train resistance is variable the coasting line is a curve, the slope becoming more nearly horizontal at lower speeds. The curvature is very slight, however, and it is reasonable to draw the coasting line straight at a slope corresponding to the train resistance at the speed at which the power is cut off. With good power brakes, a car can be stopped at any rate up to three miles per hour per second without danger or serious discomfort.

Since in this case the car is to make a run of one mile at a schedule speed of 24 miles per hour, the time required to make the run is $\frac{3600}{24} = 150$ seconds. This time includes a ten second stop, therefore the actual distance must be covered in 140 seconds. A braking rate of 1.5 miles per hour per second was specified. Then starting from the 140 second point on the base line, the braking line will be run through the 15 miles per hour point at 130 seconds, cutting the speed curve at *C*, Fig. 3. *ABC* is the curve with power on, *CE* is the braking line drawn from *E*, and *EF* is the 10 second stop. The area enclosed in the speed-time curve is a measure of the distance traveled by the car. Suppose the car runs at 10 miles per hour for 20 seconds. It will have traversed $\frac{10 \times 20}{3600} = \frac{1}{18}$ mile. Similarly, if the car runs at 20 miles per hour for 20 seconds, or at 10 miles per hour for 40 seconds, the distance traversed will be one-ninth mile. From this it is seen that one cross-section square in Fig. 3 is equivalent to one- eighteenth of a mile, that is, a speed-time curve for a one mile run must enclose an area exactly equal to 18 squares in the figure. If the car could be started instantly and brought up to a speed of 24 miles per hour, run for 150 seconds at this speed, and then stopped instantly, its speed-time curve would be the rectangle *AGHF*. In order that the curve *ABDEF* may truly represent a one mile run, its area must be equal to that of the rectangle $AGHF = 18$ squares. The part of the curve with power on, *ABC*, the stop, *EF*, and the braking line, *EC*, are fixed. Hence the only thing which may be varied to get the correct area is the position of the coast line, *BD*. The slope of the coast line is determined as previously described and is drawn in a trial position. The enclosed area is measured by a planimeter. If this area is found to be too small, the coast line is shifted upwards, the slope being kept the same, and if the area is too great, the coast line is moved downwards. This cut-and-try method is continued until the enclosed area is found to be correct.

In a similar manner the speed-time curves for any equipment may be plotted. If it should be found that with the highest reasonable rate of acceleration and no-coasting line, as in curve *ABCE*, Fig. 3, there is not sufficient area, this means that under the given conditions the equipment is not capable of making the desired schedule. In such a case, another curve must be plotted, using either larger motors or the same motors with higher speed gears.

CURRENT AND POWER INPUT CURVES

Having determined the speed-time curve, the curves of current and power input follow directly. From the characteristic curves of the motor it may be seen that when operating at a given voltage, any definite speed value always corresponds to a definite current value. In order to construct the part of the current curve after all the resistance is cut out, it is therefore only necessary to plot at any instant on the speed-time curve the current value corresponding to the speed at that time. Since the motors on a car are connected in parallel when the controller is "full on," the current per motor as shown by the characteristic curves must be multiplied by the number of motors on the car to give the current per car.

Before the controller is full on, different conditions exist. At the start, both motors are in series on a two-motor equipment. With a four-motor equipment there are two sets of two motors each, the motors of each set being connected in parallel and the two sets being in series. Hence from the moment of starting until the moment when the operation of the controller connects all the motors in parallel, the current per car is equal to the current per motor multiplied by one-half the number of motors on the car. In the case considered, 134 amperes per motor were required for an acceleration of 1.5 miles per hour per second. Hence the car will take 268 amperes while the motors are in the series position and 536 amperes in multiple. The speed of the car with motors in series without resistance, as obtained from the following relations,

$$\frac{\text{Speed in series}}{\text{Speed in parallel}} = \frac{\text{250 volts—drop in motor.}}{\text{500 volts—drop in motor.}}$$

was found to be 8.5 miles per hour. This gives the speed point at which the motors are connected in parallel and the current per car increases from 268 to 536 amperes. The car continues to take 536 amperes until all the resistance is out when the speed at 18 miles per hour is reached. At the point *B,* Fig. 3, where the power is cut off, the current falls to zero, thus completing the curve.

A curve of power input can easily be plotted from the current curve, the kilowatts input at any instant being equal to $\frac{\text{amperes} \times \text{volts.}}{1000}$. In ordinary theoretical calculations where the line pressure is assumed to be constant at 500 volts, the current and kilowatt curves will be the same if the scale of kilowatts is made double that of amperes. In Fig. 3, the curve *ARIJKLM* is the curve of current per car and kilowatts input. The voltage on each motor at any instant is shown by curve *ATVWM.*

Frequently it is not only desirable but necessary to know the average current or power taken by the car. This average is taken for the time of a complete cycle and not merely for the time during which the car is taking power. The average current is found by dividing the area of the current curve in ampere-seconds by the time of the run in seconds. In Fig. 3, the area of each square with reference to the current curve is equal to $200 \times 20 = 4\,000$ ampere-seconds. When measured by a planimeter, this curve is found to enclose an area of 4.3 squares. Hence the average current per car for the run is $\frac{4.3 \times 4000}{150} = 115$ amperes. Similarly, the average power input for the run is $\frac{4.3 \times 2000}{150} = 57.5$ kilowatts.

The above average values are dependent upon the speed at which the car travels, therefore a comparison on this basis of the performances of two cars making different schedule speeds will be unfair and is apt to be misleading. Where the performances of cars weighing exactly or nearly the same and operating under different schedule speeds are to be compared, a fair basis of comparison is found in the values of kilowatt-hours per car-mile. For the run being considered, it was found that the average power was 57.5 kilowatts. The time of the run was 150 seconds = one-twenty-fourth of an hour. Hence the energy input to the car for the run is $\frac{57.5}{24}$ = 2.4 kilowatt-hours. As in this case the run is one mile in length the energy input is 2.4 kilowatt-hours per car mile.

PERFORMANCE COMPARISONS

If the performances in two cars very different in weight are to be compared, the values of kilowatt-hours per car-mile are little better than the average kilowatts as a basis of comparison. In such cases, the watt-hours per ton-mile may be compared. The value of 2.4 kilowatt-hours per car-mile found above is for a 40-ton car. From this it follows that the energy input may be expressed as $\frac{2.4 \times 1000}{40}$ = 60 watt-hours per ton-mile for this particular case.

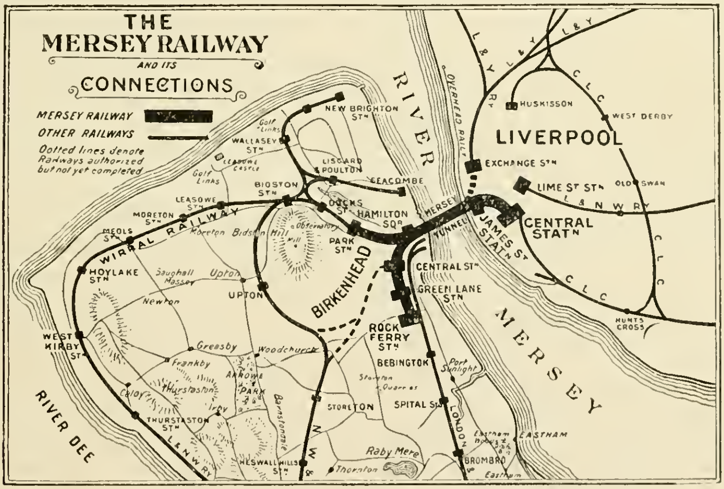
The watt-hours per ton-mile values should not be used for all cases except when all the associated conditions and the quantities affecting them are considered and duly taken into account. However, numerous cases exist where the values of watt-hours per ton-mile may be compared directly. The performances of different equipments operating the same car in a given service may be compared on this basis as may be the performances of the same equipment operating different cars in a given service and also the performance of the same equipment operating the same car under different conditions of service.

The curve *AXYZM* is plotted from the squares of the instantaneous values of current per motor. The value of the average or mean square current is determined from this curve in the same way as that used for finding the average current per car. By taking the square root of the mean square value of current per motor, a quantity is found which, taken in conjunction with the average voltage impressed on the motors, shows whether the chosen equipment is suited to the service. If the equipment is not suitable, these values further indicate whether it is too large or too small, together with the approximate amount of error.

THE MERSEY TUNNEL AND THE LONDON METROPOLITAN RAILWAY ELECTRIFICATIONS—I

H. L. KIRKER

When the Mersey Tunnel Railway between Liverpool and Birkenhead, England, was electrified, the entire steam service was abandoned and complete electric service inaugurated within the space of a few hours. When the London Metropolitan Railway was electrified, the change-over was made gradually. In the first instance the contractors' recommendation that the new service be inaugurated gradually was not adopted, in the second it was followed. In both cases the results confirmed the contractors' judgment.



MAP OF THE MERSEY RAILWAY AND ITS CONNECTIONS

To the operating engineer it is self-evident that an entire steam locomotive service cannot be replaced in a few hours by an electric service involving a new power station, new sub-stations, new rolling stock and calling for the continuous and skilled cooperation of several hundred men. But according to my experience, this is not always self-evident to the management and traffic department of steam railways, nor is it always brought to their attention sufficiently early by the contractors to minimize the trouble incident to the change-over.

The inaugural problem is a serious one, and when the railway company assumes one program and the contractor another, a dangerous compromise may have to be resorted to if the matter is left for settlement until the starting time arrives. In view of the frequency with which this problem is coming up, a few notes on the instantaneous change-over on the Mersey and the gradual change-over on the Metropolitan may be interesting. I am familiar with both of these cases, as I spent eighteen months on the Mersey contract and two years on the Metropolitan.

The Mersey Tunnel Railway was not competing successfully with the ferries. The management believed the failure to be due to bad air in the tunnel. They saw that electrification would solve the smoke problem, so after much deliberation they decided to electrify. It was asumed that financial success would date from the inauguration of the new service. The entire contract was let to one firm, who carried out the work without interfering with the steam service. As this was the first instance in the kingdom of the electrification of a steam road, the work attracted much attention. The interest increased as the work progressed and finally when the trial period approached and the program for the change-over from steam to electricity was discussed, the contractors found that the railway company was counting on a spectacular opening. They wanted an instantaneous transformation from steam to electricity. The contractors pointed out the tremendous strain to which the plant would be put if a full service was attempted at the outset. They insisted that time was necessary to test the plant and train the staff, and that the natural way to inaugurate the new service was to gradually replace the steam trains by electric ones, that with such an arrangement the little embarassments incident to the change-over would not have a serious effect on traffic and as regards the "inaugural show", it could take place like an official coronation—after the new regime was in full swing. The railway company maintained, however, that a mixed service would be prejudicial to the undertaking. They would not forego a dramatic opening and consequently the contractors had to act accordingly.

As a preliminary training for motormen, a school train was run at night during the non-traffic hours on a branch line for two or three weeks. Later two empty trains were run in between the steam trains a few hours per day for eight or ten days. A water rheostat load was put on the generator. At this juncture the railway company retained a prominent consulting engineer and he called for a test on the entire system. This test was made on a Saturday night during the non-traffic hours. The entire service of electric trains was brought out and run on the proposed three minute schedule. As a result of this run the consulting engineer recommended that the new service be inaugurated within ten days and that a complete service be instituted at the out-set.

Accordingly on Saturday night, May 2nd, 1903, all the steam rolling stock was taken out and the electric trains brought in. The first train on Sunday forenoon hauled the inaugural party over the road and a general inspection of the system took place. After this inspection the party adjourned to an elaborate banquet at which the Lord Mayor of Liverpool, the Mayor of Birkenhead, various representative railway men, manufacturers, and members of the press were present. Congratulatory speeches were made and pleasing prophesies indulged in. During the feasting the new service was thrown open to the public and an extraordinary chapter in operating was begun.

Seven hundred and fifty trains per day were scheduled to pass throught the tunnel. The road is a double track one with a branch line on the Birkenhead side and is completely controlled by a block signal system. Two hundred and fifty men were more or less directly concerned in the operation of the trains, and of these men ninety per cent were employees who had been engaged in operating the steam road. I had operated the plant during the trial runs. With commencement of the new service the railway staff took charge. This staff had been selected generally without reference to the contractors' recommendations. Their only concerted experience with electric operation was the five hour trial run made for the consulting engineer. As a precautionary measure I covered some of the more important parts of the plant with my own men. I rather hoped with the proper co-operation, to keep the railway company's staff out of serious trouble and save the plant from abuse while the men were getting a working knowledge of the new system. These expectations were not realized. There was more or less co-operation but the position was an anomalous one, as the responsibility was badly mixed. The plant had not been accepted but the railway company was operating it. The contractors were helping but had no authority. Discipline under these circumstances was almost out of the question.

For four or five weeks there was trouble, and most of it useless trouble. Sometimes it was in the power station, sometimes on the line, and sometimes with the lighting system. Passenger stations would be left in darkness, for even the gas lamps had been removed. The rust on the collectors rails caused trains to be accompanied by streams of sparks that produced a weird effect in the grimy tunnel. There were numerous delays to traffic due to small hitches in the control and brake gear. Dangling collector shoes would bring out a feeder breaker and stall trains in darkness. In the power house the situation at times was critical. There were periods when two out of the three engines were out of commission and when another minor accident to the valve gear or another hot crank pin would have shut down the entire road. The detailed report of the early mishaps is long and instructive. A few particulars will suffice.

A grounded cross-bond near the terminal station suspended traffic on that section for thirty-five minutes. A skilled man could have removed this ground in five minutes. A loose shoe bolt fouled a train and tied up the entire road for twenty minutes. An experienced man could have remedied this trouble without any delay whatever. A loaded train stood for a quarter of an hour just outside a terminal station because the driver could not release the brakes. Motors flashed on account of neglected brush holders. Several controllers were burned out because burnt contacts were not promptly renewed.

All of these incidents had their effect on traffic and on some days the sum total of the delays amounted to two hours out of the twenty. The public was not slow in expressing its disapproval, but fortunately there were no grave accidents. As soon as the staff exhausted the list of ordinary troubles improvement began. The same man seldom made the same mistake twice, so the advertised schedule was gradually attained.

Most of the power station troubles were checked before they had any effect on the train movements. Five times within the first month the control of the condensing plant was lost. On one of these occasions the automatic atmospheric valve stuck in partially open position and the station had to be run non-condensing for sixteen hours. Main engines were started up cold and in one of these instances the valve gear siezed, putting the engine out of commission for several hours. There were hot crank pins and minor troubles that made it necessary to shut down the engines for short periods. These troubles could have been anticipated by proper inspection.

The most serious mishaps occured toward the end of the first month. On the morning in question the boiler room crew was slow in getting the fires cleaned and ready for the morning load. The load caught them with low steam and pulled the pressure to a point that made the operation of the condensing plant erratic. The vacuum was lost several times. Finally the automatic atmospheric valve stuck in a partially open position, forcing the plant to run non-condensing. This increased the pull on the boilers and dropped the pressure still lower. The engines began to pound badly. The stokers, condensers and feed pumps were all giving trouble at once. The boiler room crew lost control of the situation. The water tender ran the water up too high in the boilers. This brought the pressure down to 90 pounds. Heavy priming occurred and one of the main engines took water so badly that it was barely shut down in time to escape being wrecked. The valve gear seized and eight hours forced work was necessary to get the engine into commission again. The train load was all but abandoned until the pressure was brought up again. The atmospheric valve was hopelessly stuck for the rest of the day. The third engine was partially dismantled so the train load had to be kept within the capacity of one engine running non-condensing until the damaged valve gear was repaired. Fortunately nothing happened to this remaining engine during the eight hours it had to carry the load alone, so a complete shut down was avoided.

As the road operated twenty hours per day during the week and only a few hours less on Sunday, there was barely time to make the most urgent repairs. The main effort was to keep the plant going, consequently but scant attention was given at first to the boiler tubes, stoker mechanism, feed water purifiers and economizers. The results were not immediately apparent, but scale and oil collected in the boilers to such an amount that one hundred and thirty-one tubes had to be renewed during the first four months.

It is not to be wondered at that there were some accidents. It is surprising that they were not more serious. The staff was neither better nor worse than the average. The men were being trained under high pressure. The main question was whether the plant would live through its heroic initiation. It did live through it, but the first month's operation was a severe handicap on the whole undertaking. The public was disappointed with the initial service and lost a certain amount of confidence in heavy electric traction. The staff had a bitter experience and naturally blamed all the troubles on the apparatus, and thus the usual prejudice against anything new was all the harder to dispose of. However, the routine of regular operation was gradually attained, and notwithstanding the first month's mishaps, the contractors' guarantee for the first year's operation was more than met and the plant established a record for economic running that is among the best in the kingdom.

The regret is that the strain and disappointment incident to the first month's operation should have occurred at all. It was quite unnecessary. My contention is, that had the transition period extended over six weeks instead of nine hours, with the contractors in full charge of the electric operation during the mixed service, the new system would have been brought into full swing without a serious hitch.

NOTE.—In the next issue Mr. Kirker will take up the change-over from steam to electric service on the London Metropolitan Railway and give a brief comparison of these two methods of inaugurating electric service.

ARC LIGHTING

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ALTHOUGH there are tens of thousands of enclosed arc lamps installed in all parts of the country, very little in proportion to their use has been written concerning their design, operation and maintenance. Being adapted to almost every kind of commercial circuit, their importance in the equipment of a modern central station cannot be overestimated. Broadly speaking, there are certain fundamental elements of arc lamp design which must be found in all lamps, no matter whether for alternating or direct current, multiple or series.

DETAILS OF ARC ENCLOSURE

Primarily too much attention cannot be paid to the details of the arc enclosure. The gas check, or bulb cap, as it is sometimes called must have the surface against which the inner globe rests, machined true and smooth in order to make the joint as nearly air tight as possible. This is of the greatest importance, and in the case of lamps for high tension this gas check should preferably be made of some heat resisting material with high insulating qualities, with a surface for the inner globe seat which will not corrode nor deteriorate. The finer grade of soapstone has been very successfully used for this purpose. Furthermore, in operating lamps the greatest care should be exercised in trimming to see that the inner globe rests uniformly and evenly on the finished surface of the gas check with a moderate pressure. If this pressure is too great it will result in the cracking or chipping of the inner globe, generally at the point of contact. Aside from the destruction of the inner globe the life of the carbons will be shortened directly in proportion to the amount of air admitted to the globe through the fracture. The extreme condition would be in the case of an inner globe being broken entirely so as to form no enclosure for the arc on a lamp which was not fitted with an outer globe. In this case, the life of the carbon, burning freely in the air, would be between six and seven hours, while the same carbon burning in a proper enclosure would last probably from 100 to 150 hours. So it is evident that there is no economy in using chipped or cracked inner globes, owing to the greatly decreased carbon life and the attendant disadvantage and expense of having to trim certain lamps on a circuit before the carbons in the others are burned out. Oftentimes, there is also an outage charge for such lamps which is deducted by the city or town, from the earnings of the central station. Outer globes should be kept up on street systems for the same reason, as their purpose is to protect the intensely heated surface of the inner globes against rain and snow.

BUSHINGS FOR THE CARBONS

Aside from the seat for the inner globe the most important feature of a gas check is the center, or bushing, through which the carbon passes. This center must be designed with two different and distinct ends in view, one is to provide a smooth accurately fitted bushing through which the carbons must pass freely, the clearance, however, must not be greater than a few thousandths of an inch, for if it is more the life of the carbons will be materially reduced. The second requirement, often made of this bushing is that it should act as a relief valve for the explosion of gases in the inner globe. This explosion is quite severe and takes place generally when a lamp is turned on after being out from seven to ten minuts, due to an explosive mixture of gases which forms in the inner globe. This mixture is ignited by the arc when the lamp is again switched on. To meet this requirement these bushings are arranged so as to have a slight vertical movement, allowing them to be lifted by the gases in such a manner as to open ports for equalizing the pressure with the atmosphere, thus tending to neutralize the effect of the explosion and the accompanying breakage of inner globes. The best practice in meeting these conditions seems to consist in making the gas check-plate of metal with an insulated center bushing for low tension lamps, and the reverse in high tension lamps.

The question of open and closed bottom inner globes has been debated for some time, but the best practice indicates that the closed bottom inner will soon be the standard. The closed bottom globe certainly possesses the obvious advantage of having only the one aperture to keep tightly closed in operation while the open bottom has two, with twice the chance for air leakage. Perhaps every metal and alloy which is available for ordinary manufacturing purposes has been used for carbon holders in inner bulbs, but practice has demonstrated that iron, both cast and wrought, is the only metal which will successfully withstand the heat of the arc and not be deposited on the inside of the globe either in the form of dust or a brownish scale, which unites with the glass and cannot easily be removed. It is necessary, however, to make the carbon bushing of some metal which will not oxidize as easily as iron. On account of the small clearance between it and the carbon, brass is entirely suitable for this purpose as the bushing is not really inside of the inner globe.

CLUTCHES

Almost as important as the proper enclosure and combustion conditions in the arc, is the question of the clutch. Probably more different forms of clutches have been made than any other part of the mechanism, yet viewed by present day standards, it is the simplest thing in the lamp. A clutch cannot be made of metal unless it is well insulated, which is quite a difficult matter. If it is not insulated, and the upper carbon is not firmly seated in its holder, the clutch will attempt to carry current to the carbon with the invariable result that the clutch is injured by having its edges fused at the point of contact with the carbon. Again, a clutch with many pieces, is all the more liable to get out of order, so the simplest possible clutch has been found to be most effective, that is, a porcelain ring mounted in a sheet metal basket or punching. It is mechanically strong and will never carry current.

DASH POTS

Dash pots are of like importance and should be designed and manufactured with the utmost care. The cylinders should be as round and of as uniform diameter as it is possible to obtain them, valve seats should be accurately machined and the plungers fitted with the greatest care so that each dash pot will operate in about the same time as every other one. Also they must not be affected by wide variations in temperature. To meet these requirements practically all dash pots are now being made of graphite and brass, since graphite has a practically negligible temperature coefficient, and works excellently as a plunger in a brass cylinder.

SHORT-CIRCUITING SWITCHES

The short-circuiting switch would seem to be a simple thing but it may easily be a continual source of trouble, on account of the way it is abused especially on inside lamps. In commercial service, lamps are generally hung fifteen or twenty feet from the floor and are seldom wired in such a manner as to be controlled by wall switches, so a long pole in the hands of a janitor is generally used to knock the switch back and forth. Such treatment demands a strong and simple switch. If there are no moving wires it is so much the better, as such wires harden or crystallize in the course of time and break off, making the switch useless until repaired. The best switch, therefore, is one fitted with a substantial handle, working between two positive stops and having a blade made entirely of insulating material with a contact button inserted in it, constructed in such a manner as to be forced between two stationary contacts to close the switch circuit and away from them to open. This, obviously, does away with all necessity for moving wires and provides a switch that is practically indestructible.

BINDING POSTS

Binding posts also might be considered of small importance to a superficial observer but they assume new proportions when we stop to think that in the case of series street lamps, for instance, they are exposed contacts carrying potentials as high as 10 000 volts, and in some cases, they have to perform double duty and support the supply lines leading from the pole to the lamp. Practical operation has proven that these binding posts should be compactly built, fitted with two screws, drilled out for wire as large as No. 4 B. & S. guage, and thoroughly protected by heat and moisture-proof insulation, preferably porcelain, arranged in the form of an insulator for outside service.

ALIGNMENT OF PARTS

Proper alignment should be secured in a lamp by reason of the elements of its structural design. In other words a lamp should be built so that it will be unnecessary to line it up after assembling. The parts should go together in such a way as to effectually take care of the alignment without further labor. If a lamp movement is not in proper alignment, trouble is to be expected from the upper carbon sticking, either in its guides or in the gas check center. One of the best ways to preserve alignment is to use a rigid center tube construction, with a sheath or holder inside of it for the upper carbon. In this method the sheath is connected in the circuit by means of a flexible conductor, which may be either inside or outside of the tube. The tube, however, must either be slotted or provided with some other ample means for ventilation. If this is not done the heat from the arc will be retained in the tube and will soon destroy the flexible cable. Various attempts were made in the early days of enclosed arc lighting to supply current to the upper carbon without using a cable, but one by one they proved their inadequacy and were discarded in favor of the cable which is the standard to-day.

GENERAL CONSIDERATIONS

It is very gratifying to note that many of the features of lamp construction and design which have been outlined in this article, are being carried out to-day in the best modern practice, and that arc lamp buyers in general are beginning to discriminate against cheap lamps. The time is rapidly approaching when operating men will fully realize the importance of building a lamp of the best possible material, with the highest grade of insulation that can be obtained, combined with workmanship of a good quality, and painstaking shop inspection and testing. The question may be asked as to why all this is necessary but a consideration of the conditions will make the reasons evident, especially on the high tension alternating-current series systems. Lamps for this service must operate on circuits of up to 100 lamps, with a potential of over 9 000 volts, and they must continue to operate in rain, sleet, snow, under widely varying temperature conditions and in the most exposed places. Other apparatus for such voltages is protected in every way possible by means of heavy metal cases, large porcelain insulators and is immersed in oil wherever possible. All of these methods of protection are obviously out of the question in arc lamp design, yet alternating-current series lamps must not only withstand these voltages but must accurately separate and maintain an arc between a pair of carbons. Moreover, other exposed parts of a high tension equipment are held rigidly in some such place as on a pole or a building wall, while a lamp is at the mercy of every breeze or gale that blows, being supported in most cases at the end of a light mast arm, or at the center of a slender span wire. These operating difficulties certainly indicate that it is impossible to exercise too much care in the design, manufacture and operation of lamps for outdoor service.

CLASSIFICATION OF LAMPS

In taking up the matter more specifically it should be noted that there are three broad classifications of arc lamps adapted to operate on the different commercial systems such as incandescent, power and street railway equipments. The first are generally styled multiple lamps and operate on 110 and 220 volt direct-current and 110 volt alternating-current constant potential circuits; the second class, series lamps, which operate on both alternating and direct constant current circuits, and the third class which is a combination of the first and second in which lamps operate in multiple-series on constant potential circuits. Practically all of the electrical and mechanical characteristics noted in the first part of this article are common to all of the commercial types of lamps, and in the brief specific descriptions which follow it should be understood that gas checks, clutches, dash pots, etc., have been described in detail and will only be mentioned in the descriptions as the need arises.

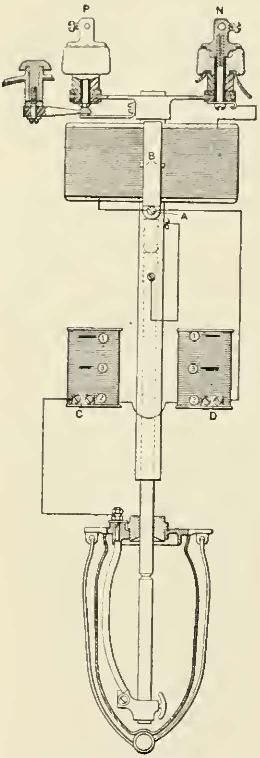


FIG. 1—CIRCUIT DIAGRAM OF A DIRECT-CURRENT, MULTIPLE, 110 AND 220 VOLT ARC LAMP

DIRECT-CURRENT MULTIPLE LAMPS

On account of so many isolated plants using 110 volts direct-current and on account of many of the larger cities having 220 volt direct-current three-wire systems a large number of arc lamps suitable for direct-current constant potential circuits are in operation. Solid carbons are invariably used in these lamps, generally a twelve inch upper and a five or five and one-half inch lower From the circuit diagram, Fig. 1, it will be seen that this lamp consists essentially of a pair of carbons, a resistance and magnets for striking the arc. A dash pot, not shown in the sketch, is used to steady the arc. On the 110 volt multiple lamp, the resistance, B, is usually wound with enough wire to enable it to be used on circuits of from 100 to 125 volts and should be set so as to have an arc voltage of approximately 80. This resistance and the magnet spools should be as nearly fireproof as possible. Much trouble was occasioned with the first enclosed arcs by reason of the resistance, which generally consisted of spring-like coils of wire stretch-ed just enough to separate the turns and prevent them from touching. Such resistances gave very poor results, for, as they heated up, the wire in the coils lengthened sufficiently to short-circuit whole sections, with the inevitable destruction of the resistance and the lamp windings. The resistance spool shown in the circuit diagram does not have this defect, consisting as it does of a large porcelain spool with such deep grooves in its outer surface, that it is impossible for the heat to stretch the wire enough to short-circuit between grooves. Such a resistance, combined with magnet spools rendered as fireproof as possible, and proper structural details, make a very satisfactory lamp. The commonest trouble is improper arc voltage. If this voltage is more than 85, the arc is liable to be very unsteady and more of the resistance should be cut in; if lower than 75 the light is poor and the carbon tips oftentimes glaze over with a sort of slag formation which seriously interferes with the proper maintenance of the arc. This condition, being the reverse of the preceding case, requires that some of the resistance be cut out. With the 220 volt direct-current lamp the arc voltage ranges from 140 to 165 at three amperes according to the voltage of the supply. Both the 110 and 220 volt lamps increase the voltage at the arcs slightly when burning with chipped or broken inner globes, and the glassware should be inspected when long or unsteady arcs are observed.

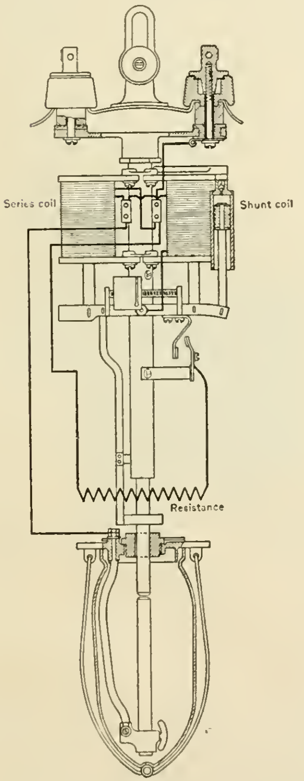


FIG. 2—CIRCUIT DIAGRAM OF A DIRECT-CURRENT SERIES AND SERIES MULTIPLE ARC LAMP

DIRECT-CURRENT SERIES LAMPS

Other lamps for the direct-current service are the series lamps for constant current circuits and the multiple-series for street railway and power circuits. The latter is practically the same as the series except that it has an arc compensating resistance which is cut in automatically if, for any reason, the lamp fails to start, thus maintaining the current as constant as possible for the remaining lamps in the series across the 500 or 220 volt mains. The circuit diagram, Fig. 2, shows the main features of this lamp—a series coil adapted to separate the carbons and strike the arc by lifting one end of a pivoted feed lever; a shunt coil working on the opposite end of the feed lever, electrically connected around the arc and arranged to work against the pull of the series coil, trip the clutch, and thus cause the carbons to feed together as they burn away. The dash pot performs its usual function in damping the movement and preventing fluctuations of the arc. The weight shown on the feed lever permits of accurate arc adjustment, being mounted on a threaded stud. A switch, not shown in the figure, is provided on the series lamp. Solid carbons are used in all cases and the arc voltage is approximately 80. The chief operating troubles are caused by unnecessary friction in the lamp mechanism and breakage of glassware, which are really general troubles and are liable to be encountered on all types. It is a good rule to follow at all times in this class of apparatus, to have everything which moves reasonably loose and free. Close adherence to this rule will save many dollars in outages in the course of a year.

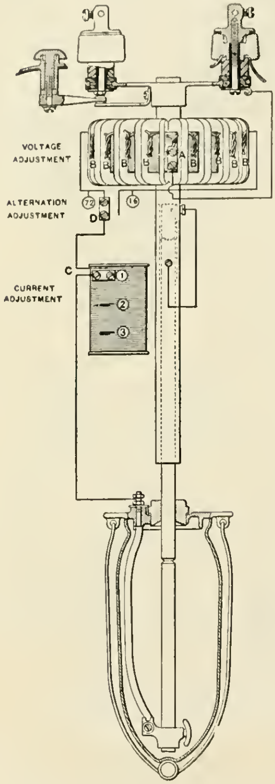


FIG. 3—CIRCUIT DIAGRAM OF AN ALTERNATING-CURRENT, MULTIPLE, 110 VOLT ARC LAMP

ALTERNATING-CURRENT MULTIPLE LAMPS

The alternating-current multiple lamp is very similar to the direct-current multiple lamp and differs from it only in a few details. A reactance coil is used instead of the resistance and the magnet cores are laminated. This constitutes the chief difference from a structural view point. Fig. 3 shows the major details of this lamp. The voltage adjustment shown on the reactance coil allows for line voltages from 100 to 125 and the alternation adjustment makes it possible to use the lamp on any frequency from 16 000 to 7 200 alternations. In special cases these lamps are operated on circuits as low as 6 000 alternations; below this the alternations become visible to the eye, which is objectionable for general commercial lighting. It is possible to make an alternating-current multiple lamp almost fool-proof which is without question a desirable attribute for any piece of electrical apparatus. This is largely accomplished by treating the coils so as to make it impossible to burn them out in a reasonable time even though the carbons should slip together. A lamp with this feature is certainly to be recommended as the necessity for repairs to windings is almost entirely, if not quite, eliminated. The arc voltage on this lamp should be about 72 volts. If set much longer the lamp will rupture the arc and chatter, if much shorter the carbons will glaze and the light will be poor.

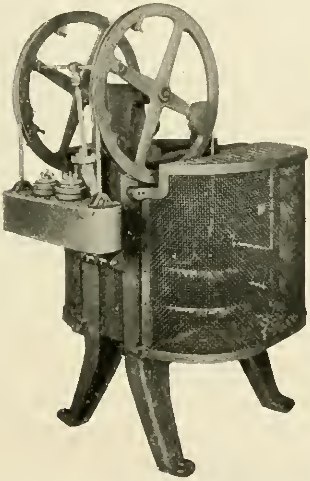


FIG. 4—CONSTANT ALTERNATING-CURRENT REGULATING TRANSFORMER

ALTERNATING-CURRENT SERIES LAMPS

The alternating-current series lamp is closely allied to the multiple lamp and has many features which are very similar. There never has been a more important advance made in arc lighting than was made by the introduction of the constant alternating-current series system suitable for operation on constant potential alternating-current bus bars. This was made possible by the constant current regulating transformer. It is primarily a transformer, receiving any commercial bus bar voltage and raising or lowering it to meet the demands of the circuit whether it be 50, 75 or 100 lamps; secondarily it is a regulator delivering a constant current from no-load to full-load. See Fig. 4.

The auxiliary apparatus pertaining to the alternating-current series system consists of a regulating transformer with the primary connected to the source of supply and with the secondary connected to the line. In this line the lamps are connected, together with suitable protective and switching devices, an ammeter, and a safety coil. From this coil, low tension leads are brought out making it possible to use the alternating-current series lamp for interior illumination.

The diagram of connections for the alternating-current series lamp is shown in Fig. 5, an inspection of which will make it evident that it is very similar to the direct-current series and multiple series lamp. The movement is a differential one with a starting resistance designed to permit just enough current to pass through the series coils to start the lamp, if the carbons are not burned out, in which case the resistance would carry the full working circuit, thus permitting the other lamps in the circuit to operate without interference. The automatic cut-out indicated in the figure is sometimes the cause of considerable trouble and should be carefully designed. The cut-out has a phosphor bronze spring faced with coin silver contacts three-eighths of an inch square. Again, the center tube construction, as shown, gives great rigidity, insures alignment, and facilitates repairs, it being possible to take out the entire movement intact and completely assembled on the center tube. Care should be exercised to have these lamps adjusted to burn an arc of 72 volts, but readings should never be taken on arc lamps of any description, if accuracy is desired, until they have been in operation for at least two hours and are thoroughly heated. Such readings should also be taken with carbons that have been burned and are of an average length. In the case of alternating-current series lamps one carbon must be cored and the other solid. Cored carbons, however, are sometimes used for both upper and lower.

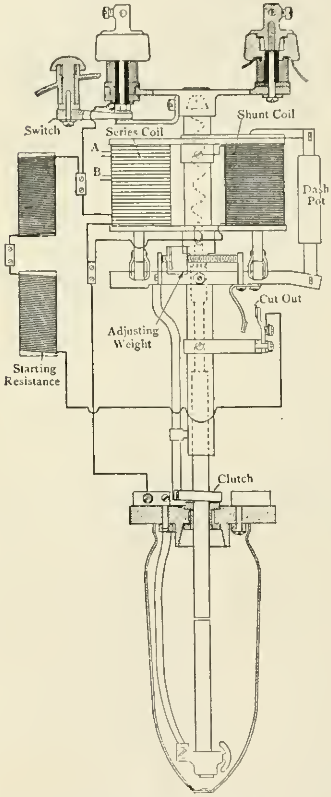


FIG. 5—CIRCUIT DIAGRAM OF AN ALTERNATING-CURRENT SERIES ARC LAMP

In general, careful attention to the length and size of carbons, accurate fitting glassware, and the habit of keeping the lamps free from dirt will be well repaid by more efficient operation and reduced outages.

THE AUXILIARY-POLE TYPE OF MOTOR

J. M. HIPPLE

DURING the last five years there has been a great extension in the use of variable speed motor drives for machine tools and other apparatus where a decided gain in efficiency or out-put is secured by the use of such drives. The appreciation of the advantages gained by having variable speed drives in such cases led at once to the application of the individual motor drive for each tool. At first the speed variation was obtained by a constant speed motor and a mechanical speed-changing device between the motor and the tool or by a combination of a small amount of speed variation in the motor and a mechanical speed-changing device. This was followed later by the use of a variable speed motor in which a wide speed range was obtained by the application of two or more voltages to the motor terminals, intermediate speeds being obtained by shunt field control. These systems, requiring as they do, a special generating and distributing system have had a rather limited application and have led to a demand for a motor in which all the speed variation desired may be obtained in the motor itself without the necessity either of a variable voltage supply or mechanical speed-changing device.

Among the various methods in use for controlling the motor speed, the simplest and most efficient, as well as the most satisfactory in speed characteristics is the single voltage direct-current system in which the variation of the motor speed is obtained by shunt field control. A constant voltage is applied to the motor armature terminals and a resistance which may be varied in amount is inserted in series with the shunt field of the motor. This resistance is commonly made in the form of a rheostat or simple type of controller. The currents to be controlled in making speed changes are small in value and therefore easily handled. The insertion of resistance in the shunt field circuit varies the strength of the magnetic field and as the strength of field is decreased the speed of the motor is increased in direct proportion.

CAUSE OF SPARKING

An ordinary shunt wound motor operating under the above conditions over a speed range of four to one will spark excessively at the brushes unless the motor is rated considerably under its normal capacity. This sparking is due principally to the weakened magnetic field and to the distortion or shifting of this field due to reaction on it by the field produced by the ampere turns in the armature. When operating a variable speed motor at the lowest speed with the full strength of field this distortion does not occur to any marked degree and the brushes can be set in a position to give sparkless commutation from no-load to a considerable overload. If the brushes are left in this position and the field weakened to give a speed four times the minimum, distortion of the field does occur and the result is that the neutral point or point of good commutation is shifted so far away from the brush position that the conditions necessary to good commutation are destroyed and sparking results.

EFFECT OF AUXILIARY FIELD

The use of an auxiliary field by correcting this condition produces sparkless commutation and a condition of practical stability of field and consequently of speed in the motor. This auxiliary field is produced by a winding in series with the armature and placed on pole-pieces midway between the main pole-pieces. The best results are obtained by so winding the coils of the auxiliary winding that all of the turns are located as near as possible to the armature surface. This applies the corrective force of the auxiliary winding directly opposite and close to the armature surface and the field produced by this winding opposes and compensates for the field produced by the armature. The distortion at the point of commutation which would occur if there was no auxiliary winding is in this way prevented by the field produced by the auxiliary winding and in addition this field assists in reversing the current in the short-circuited coil under the brush. This field being always proportional to the load the commutation is accomplished sparklessly at all loads up to heavy overloads. A motor equipped with auxiliary poles and coils of this type is shown in Fig. 1, the coils being placed in the most effective position for securing the desired results.

COMPARISON OF FIELD FORMS

The relations of the fields produced by the shunt winding, the armature and the auxiliary winding are shown in Fig. 2. These curves or field forms are plotted from measurements taken by running a five hp, 400 to 1 600 r.p.m., motor at its maximum speed and measuring the potential difference between commutator bars. These readings when plotted with voltage between bars as ordinates and the commutator bars between positive and negative brushes as abscissae, give a graphic representation of the shape of the magnetic field. The curves shown were taken under the following conditions: Curve *A* shows the potential difference between adjacent commutator bars with no load on the motor. It is therefore the field form produced by the shunt winding alone. Curve *B* shows the potential difference between commutator bars of the same motor with full load on the motor but without auxiliary poles or coils, it is therefore the field form due to the shunt winding and armature reaction. This curve shows the distortion caused by armature reaction. Curve *C* shows the potential difference between adjacent commutator bars of the same motor with full load on the motor but with the motor equipped with auxiliary poles and windings. It is therefore the field form due to the combined shunt, armature and auxiliary windings. By comparing curves *B* and *C* it may be seen that the auxiliary

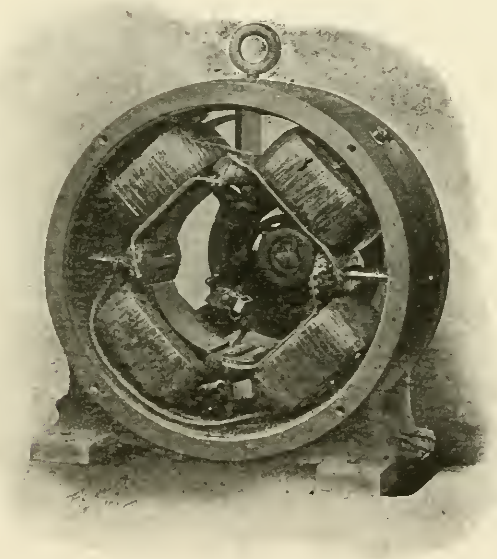


FIG. 1—VIEW OF AUXILIARY POLE MOTOR WITH ARMATURE, ONE BEARING AND END REMOVED, SHOWING ARRANGEMENT OF POLES AND FIELD WINDINGS

winding overcomes the effect of armature reaction at the brushes and produces a field of the most favorable shape for good commutation. Motors which, when operating under condition shown by curve *B*, will show vicious sparking at the brushes, will operate sparklessly under the condition shown by curve *C*. Under these conditions trouble at the commutator practically disappears and the life of the commutator is greatly increased and perfect reliability of operation assured.

The particular form of winding described above is in reality a compensating winding as well as a winding to produce a commutating field. The effect of armature reaction between the main poles is compensated for and the actual magnetic flux passing through the auxiliary poles is relatively small. The poles are therefore not saturated and even at heavy overloads the flux passing through them is proportional to the load.

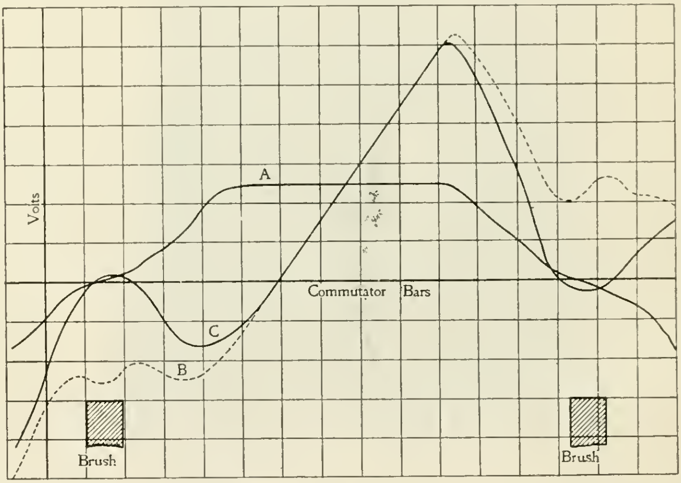


FIG. 2—CURVES SHOWING FIELD WAVE FORMS OF AUXILIARY POLE MOTORS

A—WITH NO LOAD AND SHUNT FIELDS ONLY
B—WITH FULL LOAD AND SHUNT FIELDS ONLY
C—WITH FULL LOAD AND SHUNT AND AUXILIARY FIELDS

EFFICIENCY

The efficiency of the auxiliary pole motor is practically constant for a given load at any speed within its range as the only variable losses are the core loss, friction losses and field $I^2 R$ losses. The core loss and the field $I^2 R$ losses increase with increasing speed and the friction losses increase. The losses thus tend to average up to a constant total giving approximately constant efficiency.

REGULATION

The regulation or drop in speed with increase in load is low and the percentage drop remains about the same for various speeds. Curves showing the regulation of this type of motor at the extremes of speed are shown in Fig. 3.

DIRECTION OF ROTATION

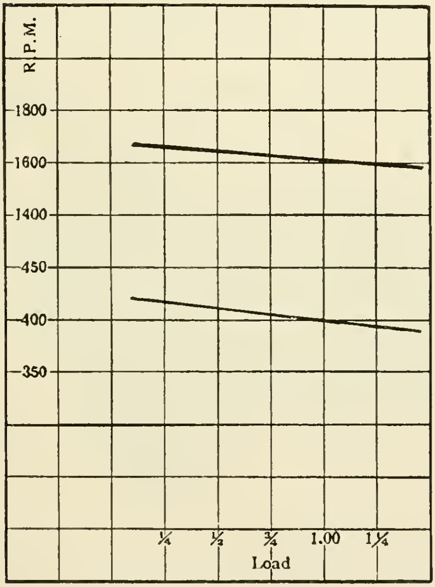


FIG. 3—CURVES SHOWING REGULATION AT 400 R.P.M. AND AT 1600 R.P.M. OF A 220-VOLT, 5-HORSE POWER MOTOR

Motors of this type are reversible with no change in setting of brushes or other adjustment. The brushes being fixed in the neutral position it is only necessary to reverse the current in both auxiliary field and armature to secure exactly similar operating conditions in the reverse as in the forward direction.

One way of making clear the action of the auxiliary pole motor is to consider an auxiliary pole as the pole tip of one of its adjacent main poles. The fringe of magnetic lines under the tip of the main pole piece in an ordinary motor is of great assistance in commutating the armature current. In the auxiliary pole type of motor the auxiliary pole acts as the pole tip of the adjacent pole and the fringe of lines under it is proportional in amount to the strength of the armature current, thus giving an ideal condition for commutation. In reversing the motor, since the current in the auxiliary winding is reversed, the auxiliary pole acts as the tip of the other adjacent main pole. Exactly similar conditions therefore prevail for either direction of rotation.

THE ELECTRIC VEHICLE

ITS PRESENT STATUS AND ITS RELATION TO THE CENTRAL STATION

HAYDEN EAMES

MOST people base their opinions upon the relative excellence or suitability of various types or makes of automobiles or power wagons upon the off-hand declaration of some more or less—generally less—well informed acquaintance who frequently makes up by the emphasis of his statements, whatever lack of comprehensive information he may have on the subject.

There are so many good makes of American gasoline touring cars and electric pleasure vehicles that the resulting selection not infrequently tends to enhance the usually undeserved reputation of the alleged expert.

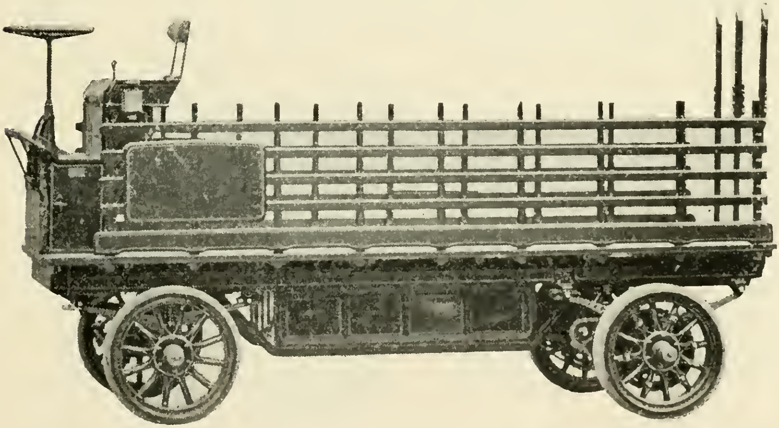
When it comes to types of business wagons, and the form of power most suited to wagons for any given purpose, something more is required than a general engineering education, casual observation on a particular type of wagon and an assertive manner, to keep from getting into trouble—or at least, to make the most suitable selection.

In considering the question of power wagons, urban service and interurban service must be separately considered. The data, considerations and principles controlling one service are quite different from those controlling the other.

We will confine ourselves in this article to city service where both gasoline and electric vehicles have their respective places and in which they offer superior economy over any other form of transportation. While the conditions are so various that no definite law can be laid down to-day as to the relative suitability of application of these two kinds of power to various purposes, or even a law governing the majority of cases, it can in general be stated that under some traffic conditions and surface requirements the superior mobility of the gasoline vehicle makes the saving in drivers great enough to compensate for the higher maintenance charges. Where the limitations are such, however, that the number of active vehicles required has to be about the same in each case, the electric vehicle becomes more economical on account of its lower maintenance charge. Of course the gasoline vehicle has the advantage in all fields requiring mileage beyond that safely and conveniently obtained by the electric, but the greater proportion of city delivery service is well within the radius of travel of the electric vehicle.

With this general preliminary statement, we may omit the gasoline vehicle from consideration as being of secondary interest to the lighting and power station operators to whom this article is expected to be of especial interest.

In view of the greatly advertised and somewhat disastrous experiences of the various so-called transportation companies in attempting to operate cab service in several of our larger cities some five or six years ago, we assume that this particular class of readers must have obtained a very adverse idea of the commercial possibilities of the electric vehicle, more especially as the local light and power companies were supposed to have been almost invariably heavily interested as stockholders in these ventures. At least one of these ventures, which was subsequently abandoned, contained every element of practical success except a single-minded management. The circumstances which led to its abandonment were of such a nature that they can hardly be designated as due to incompetence. It must be obvious that the employment of an entirely new and necessarily somewhat imperfect contrivance, in an entirely new kind of service, embodying many details as yet in a backward state of development in their special application, required men not only of resource, but of single-minded determination to succeed. In this particular instance men of resource there were, and the ordinary



FIVE-TON ELECTRIC TRUCK

Gear speed 6.4 miles per hour. Battery capacity about 20 miles. Length over all, 17 feet. Weight complete 9700 lbs.

difficulties which might be expected under the circumstances were more or less easily overcome; the engineering difficulties to which one would naturally look for the failure of such an organization were kept well under control and within limits, and the failure of the station in this case was *not* due to the shortcomings of "the electric automobile", but to performances which it would be hardly suitable or necessary for us to enter into here, but which had no real bearing upon the question of the operation of electric automobile cabs, even five or six years ago. The liquidation or abandonment of all the other similar ventures in this country except one, while not due to the same causes as in the case above cited, were due to administrative causes equally unessential to the consideration of the possibilities of the electric automobile for such service. In the remaining and existing case it is generally supposed that their receipts considerably exceed the expenditures; that in spite of many expensive and adverse inheritances, the company does not and is not expected to lose money—a really remarkable circumstance in view of the somewhat ill-advised conditions under which it was started.

A similar adventure in London came to an adverse conclusion because it was started simply as an auxiliary to the exploitation of a certain storage battery company instead of with the sole view of legitimate commercial profit in itself.

It seems appropriate to refer to these circumstances as the wide advertisement which they received through their large number of stockholders and from other similar causes, accentuating the results without revealing the somewhat complex causes, has played a larger part as a basis of judgment as to the economy of electric vehicles than probably any other single collection of facts or experiences. It seems desirable to explicitly state at the beginning, therefore, that the causes producing the adverse results in these special cases were in general entirely apart from any question as to the practicability or economy of the vehicles themselves, even of the somewhat imperfect designs of that day.

Now as to the present facts: I have before me one hundred and four communications from users of electric business wagons of various makes. Of these forty pronounce their new service eminently satisfactory, after a period varying from five or six months to several years. Twenty-two more pronounce the service satisfactory and of advantage over their previous use of draft animals, but with possibly less enthusiasm than the first forty; of the remainder, all but twenty are ambiguous. Of these twenty, fourteen pronounce themselves as unsatisfied for various alleged causes, although in the majority of instances the real cause is unconsciously revealed in the communication. Six only, out of the one hundred and four, positively condemn the new method. In this connection it is very interesting to note that among those condemning is one user operating a vehicle in the same service and in the same town as another vehicle of the same type, pronounced by the other user to be eminently satisfactory. In this case it is a question of "knowing how to use the new tool," and this is generally the difficulty. "The world marks the hits but not the misses"—and all cases of failure are actively advertised, but the power wagon has now developed to a point where successes are taken as a matter of course,

ELECTRIC EXPRESS WAGON

Carrying capacity, 2500 lbs. Maximum speed, 10 miles per hour. Length over all, 14 feet, 7 inches. Weight complete, 4800 lbs.

without regard to the resulting original inconsistency involved thereby. This is of course a good sign of mental development, but it tends to postpone the day when those who enjoy the enumeration of failures will take the trouble to so inform themselves as to reap the harvest which must necessarily result to all important electrical interests when this form of motive power is generally introduced.

Very few of those with electrical engineering educations realize that the manual care of an electric automobile or an electric storage battery is a specialty. They seem to assume as a matter of course that if one is familiar with the care and operation of a stationary storage battery, or even if one is familiar with the electrochemical reactions taking place in a storage battery, that he is fully equipped to care for the storage battery in an electric automobile, but experience has proven that this is conspicuously and unfortunately not so. The best performances of storage battery vehicles covering considerable periods have been made under the immediate supervision of relatively scientifically ignorant men, who have had an opportunity to thoroughly familiarize themselves manually with the problem at hand, and who are themselves of superior natural intelligence.

The most satisfactory urban transportation of merchandise, and the cheapest of which we have any knowledge, is the Adams Express service in Buffalo. The station there has been in charge of a man of the widest experience in the oversight and manual operation of electric vehicles and power wagons of all kinds, who is adequately supported by an agent with foresight. While the information before us is hardly wide enough to warrant a positive statement, we have little hesitation in venturing the assertion that this particular installation has not its superior in the world for economy and delivery. If this can be done by proper management at Buffalo it can be done elsewhere, and if the local electric light and power station refrains from attempting to "kill the goose that lays the golden egg," and if in common with almost all other commercial ventures, it is willing to make minor present sacrifices for large future gain, it can profit greatly by similar operations in its own territory.

In considering the expense of operation of electric automobiles it must be borne in mind that the largest single item of expense is the driver; the next most important item is that of maintenance, including the storage battery, which should be treated as an expense account rather than an investment, as it is really "slow fuel." Under ordinary circumstances all the other questions are of minor consequence.

It must also be borne in mind that in considering depreciation and interest a storage battery with promptly renewed elements and properly maintained, together with the motive power, or at least the motors themselves, remain in good condition and available for application to other vehicles when the structure of the vehicle to which they are applied has worn out. This is not speculation, but has actually occurred.

A very considerable item in the maintenance of vehicles lies in the rubber tires. These are very desirable, if not a necessity, upon vehicles for the transportation of loads of (teamsters' rating) under 2 000 pounds. Above that rating vehicles can be advantageously equipped, in the majority of cases, with wood or iron tires, according to circumstances, although in very many cases throughout the list rubber tires will be used as a luxury, if nothing else, but in the heavier applications they should be regarded and treated as such, and their expense of maintenance not charged against the vehicle as an essential. The best performance we have available on the part of any express wagon was that of two years' service of an express wagon in the use of one of the largest express companies in Pittsburg, Pa. This vehicle was equipped with iron tires. The express agent who had the matter in charge had the unusual, practical grasp of the situation to begin the experiment by withdrawing all the horse wagons engaged on the particular service before applying the electric wagon to it. He began, therefore, by trying to replace four single-horse wagons with one electric wagon of the same "rated load" capacity and requiring the local sub-agent to do the work with it. As a result of this sensible and business-like method of procedure in applying any kind of a labor-saving device, only one of the four horse wagons was put back into the district, and this was simply necessary as an available wagon for momentary requirements when the electric wagon was engaged in its routine delivery.

It would be perfectly true, therefore, that, thanks to the administrative capacity of the local agent in appreciating the possibilities of the electric wagon, the latter accomplished something more than the work previously done by three horse wagons of the same rated load, but rather than introduce the assumptions required to make the comparison exact, the table given below assumes that the electric wagon did the work of the three wagons which it actually replaced.

It is interesting in this connection to note that owing to the intelligent manner in which tire-calks were applied and winter conditions met, there were several occasions when the electric wagon did the entire work of the district, as the icy streets prevented the use of the horse wagons.

It would undoubtedly be no exaggeration to say that in the two weeks preceding Christmas, 1902, this one electric wagon easily did the work of five single horse wagons under the adverse weather conditions then existing. It must not be assumed from this that this is a performance that can be invariably expected. The agent was a man who would not stand for defeat, and when his sub-agent used the words "can not," the agent himself had to be shown. But what was accomplished in this case can be accomplished in almost any other case, but it would be hardly correct to say that it is likely to be, because men are rare who are able to get the best out of any piece of apparatus, especially if it happens to be of a novel character.

The following is the express agent's own statement of the comparative conditions which his memorandum showed at the end of the first year, and in so far as they were assumptions were more than confirmed to the end of the service. This table has been published before, but in its details is such an excellent illustration of the principles of accounting that should govern work of this kind that it is worth while to insert it here:

HORSE WAGONS

INVESTMENT		ANNUAL EXPENSE		
3 Wagons at $175	$ 525	Interest at 6%		$ 69 90
4 Horses at $160	640	WAGONS		
Total rolling stock	$1165	Depreciation at 10%	$ 52 50	
		Repairs at $35	105 00	$ 157 50
		HORSES		
		Depreciation at 20%	$ 128 00	
		Feed, shoeing, care and stable expense at $28.75 per month $345 per annum	$1380 00	
		Blankets, stable fixtures, harness at $3 per month, $36 per annum	144 00	$1652 00
		MEN		
		3 at $45 per month		1620 00
				$3499 40

ELECTRIC WAGONS

INVESTMENT		ANNUAL EXPENSE		
Total rolling stock	$1925	Interest at 6%		$ 115 50
Deduct 1¼ batteries at $500	625	BATTERIES		
Wagon without battery	$1300	Electric current, care and renewals of 2 sets of positives and 1 set of negatives per annum		400 00
Deduct Motors	300	WAGON		
Wagon and remainder of equipment	$1000	Depreciation of motor 5%		15 00
		Depreciation of remainder of wagon at 10%		100 00
		Mechanical repairs at $9 per month		108 00
		MEN		
		1 at $60 per month	$720 00	
		1 at $45 per month	540 00	$1260 00
				$1998 50

Annual saving Electric over Horse Wagon..................$1500 90

It must be understood that this vehicle ran winter and summer, and that when ice and snow were on the ground the tires were calked or "sharp-shod." This winter shoeing can be readily accomplished on either iron, wood or rubber tires in a variety of ways which are entirely satisfactory, for any latitude or locality in which wheeled vehicles of any kind generally run in the winter.

As an example of the peculiarly meretricious causes that tend to retard the introduction of automobiles, it is surprising to observe the crude methods of tire-calking in use, even in successful installations, when so many perfectly satisfactory methods are available.

The available data on the subject of cost of operation of various sizes and types of electric vehicles is not by any means meager. It will probably come, happily, as a surprise to know that in reasonably severe service and with proper care a light wagon, such as is used by laundries or milliners, can be easily operated for between $500 and $600 per annum, including interest and depreciation, all forms of renewal, but not including driver. This is on a basis of four cents per kw-hour at the switchboard for charging current. On the same basis a five-ton truck can be operated for $1 500 per year.

In order to get the best economy from an automobile installation the vehicle must be treated as a labor-saving machine, and this immediately leads to another cause of the "brain-fog" which generally pervades the introduction of power wagons. With our engineering educations, based mainly on railway practice, it is very natural that we should turn to the "ton-mile per vehicle," or some other similar basis of comparison; but experience has shown that such a basis is just enough removed from the actual "constant" as to be decidedly misleading.

The real question which it is necessary for us to ask in considering the substitution of power wagons for draft animals in a given case is: How much less will the power wagon cost than the draft animals to affect the entire service? And in this consideration should be considered the necessary cost of the original stationary installation and stable investments and expenses generally. In one case that has come under our attention, the cost of the stationary stable investments for electric vehicles to accomplish a given service was 20 000 odd dollars, as compared to $80 000 for the stationary investment for the corresponding horse stable, and we have no reason to believe that this was an unusual case. In fact, it was fairly representative of a very common kind of service.

It frequently happens that upon investigation of a given service the re-arrangement of routes made possible by the superior speed and endurance of the power wagons in itself effects a considerable saving in addition to that saving in the number of wagons which results from the cumulative effect of a number of minor causes, which experience has shown to be very effective when taken together. In many cases a change in the size of all or part of the wagons is made possible by the superiorities of the power wagon, and a very considerable saving in drivers and other items affected thereby. It must be obvious that these considerations all tend to make the gross requirements of the service the only real constant which can form a true basis of comparison. Happily, the margin of advantage in favor of the power wagon when reasonably well cared for is so great that many of these advantages can be neglected and still preserve some of this advantage.

All of the above statements are based not on one or two instances, but on data variously collected during an investigation of some seven or eight years. There has been almost no change in the essential details of electric power wagons for some years past, and the engineering problems to accomplish the above results have all been solved. The subsequent retarding influence to their introduction has been mainly due to lack of data on the part of the public and partial ignorance on the part of all concerned, coupled with a natural hesitancy resulting from the wide advertisement of the unfortunate experiences referred to in the first part of this article. It is high time that the electric light and power companies were taking some steps to insure that they shall themselves profit in some way from this prospective greatly increased demand for current.

One of the first requirements to such action is that they shall take the trouble to properly inform themselves as to the prospects, and having satisfactorily assured themselves on that point, to take the necessary steps to encourage and advertise the introduction of the (to them) profitable new method in the territory fed by their wires. With the proper man in charge of the station, one of the most lucrative ventures of which we have any knowledge is that of a local contract delivery service involving the use of possibly 100 light wagons, operated together on behalf of a number of customers, whose individual requirements may not exceed five or six vehicles apiece, and one relatively expensive expert can oversee one hundred of these wagons or more, just as well as he can one or two. The reason for this must be obvious.

These vehicles require comparatively little care, but they require it of the right kind, and when they get it of the right kind they are an extremely lucrative possession. Contracts of this kind can be made on the basis of a stated figure per package and be decidedly to the advantage of both customer and contractor under proper conditions of management and in comparison with draft animal service at present employed.

Another field in which the electric light and power company can afford to take heed, and immediate heed, is that of the pleasure automobile. It will probably come as a surprise to those outside of New York City to know that one electric company alone is having a very active sale for electric broughams, and that this sale is continually growing. We have had no opportunity to verify the figures, but our own observation and experience leads us to credit the statement that these are being sold by them at the rate of one per day, and have been for some time. The demand to-day for electric phætons exceeds the supply, and this is true of practically all kinds of electric vehicles.

The writer operated a Columbia electric runabout in Pittsburg for two years at a gross expense for all charges, except interest and depreciation, of slightly under $8.00 per month. The battery in this case, however, was intelligently left alone, and the garage people were not allowed to tamper with it except to charge it and correct the specific gravity of the electrolyte. We have come across a number of instances in Cleveland where Baker electric runabouts have been operated for less than $70.00 per year. We do not wish to be understood as saying that this is the rule. It is at present the exception, but there is no reason why it should not be the rule. We know of many cases of possible customers for vehicles of this kind in the suburbs of several cities who are deterred from using them by the distance of the nearest garage available for charging, and the desire to avoid installing a charging plant of their own on rented premises. We believe the time has come when the electric light and power companies can profitably consider the question of leasing individual charging apparatus especially suited to the proper use of of their own current for charging private vehicles. A comparatively few figures will indicate that this can be profitably done under conditions and at a price which will be very far from prohibitive for this class of customer.

In this article we have not by any means attempted to cover the ground and have endeavored to confine our details and figures only to those which were essential to an illustration of the principles involved and an understanding of the lessons learned. If the electric light and power companies at present in existence do not take advantage of this active opportunity, it will certainly be done by independent capital, to their great disadvantage and they will find themselves entirely deprived of this new and important source of revenue by the extended operation of influences similar to those that have recently operated to curtail their own present business in many of our cities.

THREE-WIRE DIRECT-CURRENT GENERATORS*

A. H. McINTIRE

THE three-wire system was first made use of in order to obtain the saving in conductors which is possible by this method. It is now in general use for lighting and power distribution.

If a comparison between the two-wire and the three-wire systems be made for any given case it will be found that for a given percentage drop in potential, if the three-wire system be operated with a voltage between the outer wires and the neutral equal to that of the two-wire circuit, and if the middle or neutral wire be of the same size as the outer wires, a saving in copper of 62.5 per cent may be obtained. Ordinarily the circuits are so arranged that the load is distributed uniformly between the neutral and outer wires and thus receives the same voltage as it would in the ordinary two-wire system. Making the neutral wire of the same size as the outer wire may seem in many cases an unnecessary precaution, especially when the loads on each side of the neutral are arranged so that they are nearly balanced, yet there is always the liability of the fuse blowing or the circuit breaker opening on one of the outer wires and thus throwing the whole current flowing in the other outer wire through the neutral wire. Hence, it has become customary to make the neutral of the same size as the outer wires.

In the earlier installations of the three-wire system it was necessary to use two separate generators in series, with the neutral wire joined to the common connection. By this method it was always necessary to have at least two machines in operation, however small the load. Another method that came into use later was the use of balancer sets with a single two-wire machine.

These balancer sets added somewhat to the complication as the operation of the whole system was dependent upon the continous operation of the balancer sets.

The three-wire generator was designed for the purpose of obtaining the advantages of the three-wire system without the necessity of running two separate machines. It also gives the advantage of the increased efficiency of one large machine over two small ones. The main features of the three-wire generator are the same as those of the ordinary direct-current generator. For a given service a three-wire generator would be used giving the same voltage as the two generators in series in a two-machine three-wire system.

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*Based primarily on a lecture by Mr. W. A. Dick, before The Electric Club.

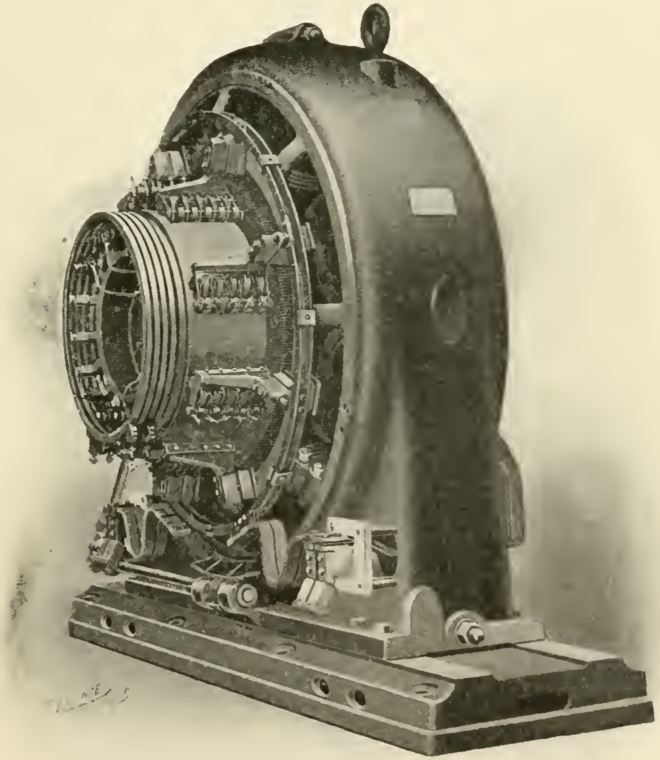

FIG. 1—300 KW ENGINE TYPE THREE-WIRE DIRECT-CURRENT GENERATOR

To change an ordinary direct-current machine into a three-wire machine it is fitted with four slip rings as shown in Fig. 1. These are connected to the armature winding in the same manner as if the machine was a two-phase rotary converter; that is, taps are brought out at four electrically equidistant points for each pair of poles and connected to the slip rings. From these rings wires are run to balance coils as shown in Fig. 2. In the earlier machines but one balancing coil was used. The action of the coil in balancing the voltage on this type of machine may be seen in Figs. 3 and 4. For the simplest case, that of a two-pole machine, the coil is connected through the slip rings to diametrically opposite points in the armature winding, as at *C* and *D*. If the machine is in operation, then, at the instant that the points *C* and *D* correspond to the points *A* and *B* as in Fig. 3, it is evident that the point *E* at the middle of the balance coil winding has a potential midway between *A* and *B*. In other positions of the armature, as in Fig. 4, the voltage between *A* and *E* is evidently always equal to that between *B* and *E*, because *CE* is always equal to *DE* and *BC* to *AD*. Therefore the resultant of *AD* and *DE* equals the resultant of *BC* and *CE*. This is true of the no-load condition or a balanced condition where no current is flowing in the neutral wire. As a load comes on one of the side circuits a slight shifting of the neutral point takes place, the voltage of the loaded side being a trifle lower. This is due to the ohmic drop in the leads and coils. These are made large in order to make the ohmic drop very small.

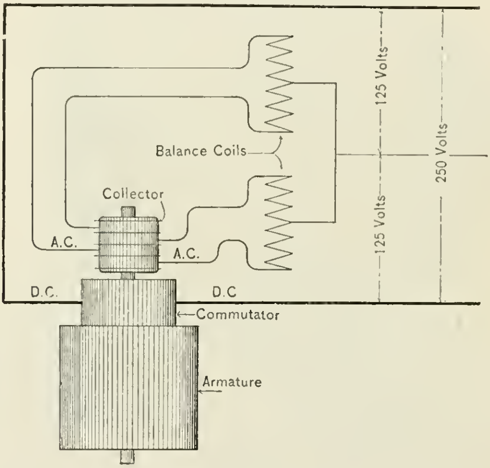

FIG. 2—DIAGRAM OF CONNECTIONS FOR A THREE-WIRE GENERATOR

Three-wire machines are ordinarily designed to take care of a 25 per cent unbalance; that is, to operate satisfactorily with 25 per cent of the full-load current of the generator flowing in the the neutral wire. This means that this is the amount of load on one of the side circuits in excess of that on the other side. Under conditions of operation with 25 per cent unbalance, the regulation is good, the voltage varying not more than two per cent from normal.

In the later types of machines two coils are used and their middle points connected together, as it was found that in this way any unbalanced current in the armature winding was more evenly distributed.

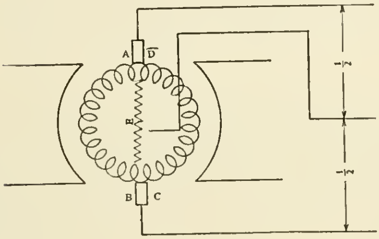

FIG. 3

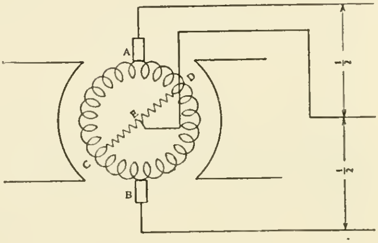

FIG. 4

The balance coils are each made of a single winding, with a neutral tap brought out from the middle point. The winding is wound on a laminated core of the shell type and mounted in a case like a small transformer. The series field windings of all the north poles are connected in series and to one outer wire, and the series all the south poles are connected to the other outer wire. This is done to obtain a compounding effect from either side of the system when the load is unbalanced. See Fig. 5. The slip rings of the three-wire generators are large in diameter, but this is for mechanical convenience rather than any electrical necessity. They are made so that they come in line with the commutator and thus one brush rigging can be used for both commutator and slip ring.

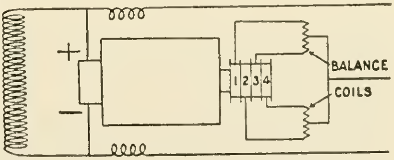

FIG. 5

Three-wire generators may be operated in parallel with each other and in parallel with two-wire machines. Thus a 250-volt, three-wire machine may be operated in parallel with two 125-volt, two-wire machines in series, or in parallel with 125-volt, two-wire machines on either side of the neutral or in parallel with

250-volt, two-wire machines. The connections for operating two three-wire generators in parallel and all necessary switch and instrument connections are shown in Fig. 6. In operating in parallel it is unnecessary to synchronize the alternating-current ends of the machines and no attention need be paid to the periodicity of the alternating currents generated by the different machines. The only conditions to be met in operating any combination of two-wire and the three-wire machines in parallel is that the machines be of the proper voltage and that suitable equalizer connections be made.

The applications of three-wire machines have been various and include manufacturing plants, office buildings, apartment houses, railway stations, etc., using both light and power from the same circuits.

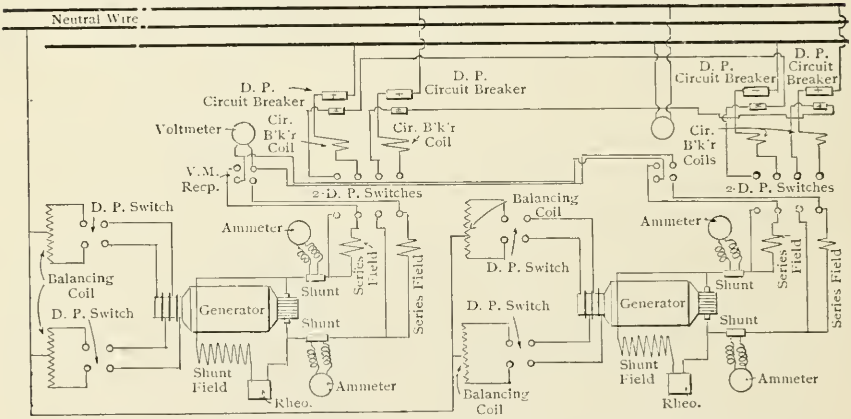

FIG. 6—DIAGRAM OF CONNECTIONS FOR OPERATING TWO THREE-WIRE GENERATORS IN PARALLEL WITH ALL NECESSARY SWITCHES AND INSTRUMENTS

In addition to the above applications of the three-wire system in which three-wire generators are being used there is quite a promising field for this machine in mining work. For this service, 500 volt, three-wire machines are used and the neutral wire is grounded. The outer wires are connected to different sections of the trolley lines in such a way as to obtain as good a balance as is desirable. In this way the benefit of the high voltage is obtained for transmission, yet operation in the mine is with the usual 250 volt circuits. In addition there is the further advantage that stationary motors for fans, pumps, etc., may be operated on the higher voltage.

THE AUTOCRAT OF THE BUSINESS WORLD*

THE technical man is the autocrat of the business world. His genius is the foundation of a large majority of commercial enterprises, and on his advice almost every undertaking depends for success.

The technical man comes closer to the life of every great business than any other class of worker. This is shown by the fact that an unusually large number of men in responsible executive positions are men with technical training. The presidents of the largest railway systems of America, as well as sixty per cent. of the higher executive officials in the steel industry, are men with engineering education.

The comparatively small supply of technical men is not due to any unwillingness on the part of employers to pay adequate salaries. It is not a question of price, but of getting the right men and enough of them.

Only recently a large manufacturing company sent a representative to Pittsburgh with instructions to pay anything within reason for from fifty to a hundred experienced draughtsmen and engineers. He was able to secure less than forty, and he had to pay them from twenty to forty per cent. more than they were receiving to induce them to change.

More difficult to find even than the purely technical man, is the man who combines with his technical training, selling or executive ability, or both. The engineer is too often purely an engineer, without the personality or inclination to sell goods or get results from other men. Many men are prejudiced against outside work, feeling that it is below their dignity. This is a great mistake, for there is no position offering better opportunity to acquire broad experience and earn a large income than that of salesman. To succeed at it, however, a man should have a magnetic personality, quick wits and unbounded grit and energy.

Technical men know their own value better than any other class of employees, and unless a business will stand frequent changes the employer must be prepared to pay them the full market price. Even by doing this it is difficult to insure their permanency, as competitors will be constantly trying to hire away your best men.

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*Extracts from an article by Herbert J. Hapgood in "System" for April 1906.

As almost every employer wants in his technical departments men trained in his own business, the best method is to take on young men fresh from the technical schools, and train them up to suit particular requirements. This, however, is easier said than done, as the young technical graduate is as much in demand as the man of experience. Last year every man in the graduating class of a well known technical school had at least three offers of employment, and some of the more capable men had as many as ten.

Two of the large manufacturing companies alone employ every year between six and seven hundred young graduates. They have established such a reputation for the training they give that they are able to secure the best men far below the market price. They train these men up in the various departments, advancing them as they prove their ability; but even with such a large number growing up in the business, their supply of men is never adequate. Of course, a certain percentage of these men leave before they have become of any great value, but the companies believe the training they give them is a good investment, because some of these men will later become chief engineers, superintendents, and so on, and when buying machinery will likely give preference to the line with which they had their first experience.

GRAPHIC RECORDING METERS

AS the necessity for obtaining accurate records becomes more apparent to central station operators, means of obtaining these records automatically are demanded. Indicating instruments were first used and the station attendants were required to record the readings of the meters on tabulated sheets at frequent intervals, and from these records curves could be drawn showing graphically the meter readings and their variations. But this method aside from the extra attention required from the switch-board attendants is more or less inaccurate as the readings are rarely taken at less than 15 minute intervals and even if arranged to be taken at shorter intervals, there are times when the attendants find it inconvenient to take the readings and are quite likely to get into the habit of estimating the readings and filling in the blanks. In addition after the records have been tabulated there is much clerical work involved in making corrections for the inaccuracies of the different instruments and in plotting the curves for each day.

Integrating meters give accurate records of the total energy consumption but do not give any idea of the load variation, and even with them readings have to be taken at regular intervals.

Graphical meters have been in use for some time, mostly for use as voltmeters and ammeters, but these have been either of the type that makes a record on a circular sheet which has to be replaced each day, or of the type which makes a record on a sheet or roll of paper with curved co-ordinates.

The new type of graphical recording meters shown in Fig. 1 makes a record on a continuous sheet of paper ruled with rectangular co-ordinates. The motion of the pen across the paper is proportional to the quantity to be measured and the speed of the cross-section paper is controlled by an electrically self-winding clock. It is thus possible to integrate any part of the record by the use of a planimeter or other means. The voltmeters, ammeters and wattmeters operate on the principle of the Kelvin balance, the actual recording, however, being done through a relay. Different instruments of this type are made to record voltage, current, power, frequency, or power factor.

The arrangement of the circuits shown in Fig. 2 is for a voltmeter. By following out the circuit from the supply circuit it may be seen that the current will flow first through the usual voltmeter resistance and then through the fixed and movable coils. The movable coil element is balanced on knife-edged supports and is provided at one end with a contact arm, which is free to move up and down between two fixed contacts. This motion up and down between these contacts is all that is required of the movable element and the making of the circuits through either contact brings the relay into operation. Any convenient source of energy may be used to operate the relay. In this case it is represented as a battery. The condensers *K* and the resistance *R* are used to eliminate sparking at the contacts. When contact is made either by the upward or downward motion of the contact arm the circuit is closed and current will flow through one of the solenoid coils *C*. Within each coil is a plunger *P* attached to the recording mechanism *M*, as shown. When the circuit is closed through the upper contact the left-hand coil will pull its plunger down, and thus by means of the relay mechanism move the pen across the record paper. When the circuit is closed through the lower contact the right-hand coil

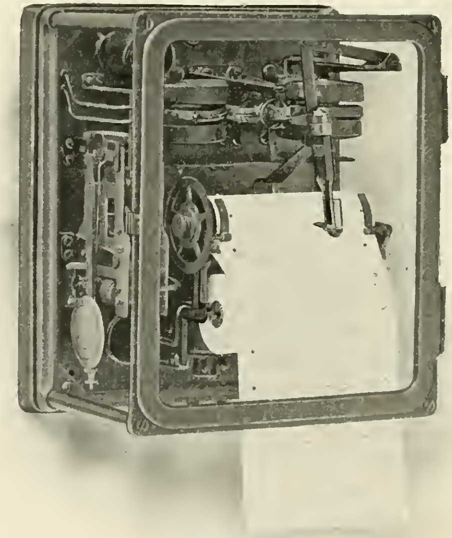

FIG. 1—GRAPHICAL RECORDING VOLTMETER

will pull its plunger down, causing the pen to move in the opposite direction. Thus a current through either relay coil will cause the corresponding plunger and hence the pen mechanism to move until the circuit is broken. The spring *S* connects the recording mechanism with the movable element. When one of the plungers has been moved by the pull exerted by its solenoid until the tension in the spring balances the force exerted by the movable element, the circuit will be broken and the motion stopped. The recording mechanism is arranged in such a way that the pen point must move in a straight line across the cross-section paper.

Friction does not enter as an element in the accuracy of the instrument for after the contact is once closed by the motion of the movable element it remains closed until the relay circuit moves the pen to the exact position corresponding to the torque of the meter element. Thus the torque exerted by the movable element is constantly balanced by the force exerted by the relay mechanism through the spring. As the supply circuit does not operate the pen mechanism it is not necessary to have an exceedingly light weight pen. The pen used is made of glass and is provided with a reservoir of sufficient size to hold ink for a continuous record of two months.

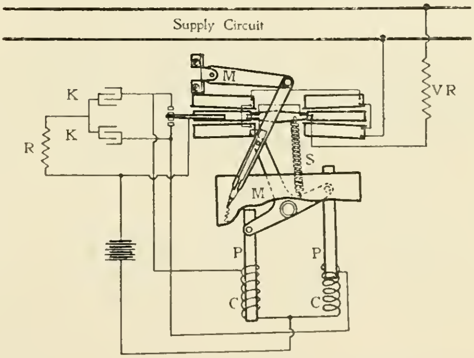

FIG. 2—OUTLINE DIAGRAM AND CONNECTIONS OF A GRAPHICAL RECORDING VOLTMETER.

The rate of motion of the paper may be varied to suit different cases. Two inches per hour is the speed most commonly used.

These instruments are provided with adjustments to control the sensitiveness of the instruments.

The quickness of the pen's motion may be regulated by adjusting a pair of dash pots connected to the moveable element.

The sensitiveness of the motion may be varied by changing the spacing between the fixed contacts.

By these two methods of adjustment the pen may be made either to follow the slightest changes or to slur over the quick variations and give a more even curve.

"THE RECEEPROCATIN' MON"

(By Robert Burns and others, including Gavin Hamilton)

Oh! woesome 'oor that saw the birth,
O turbine thochts in Pairsons heid.
I weesh that I wis aff the earth,
Or else the turbine men wis deid.

I'm a receeprocatin' mon;
I luve tae hear the bearin' bump,
Or yet, the piston groan and grunt
That's religated tae a pump.

This whurligeegin' thing I hate,
For whutna gude is it tae dae?
Tae sae the fearsome thing gyrate
Gars me piur stummuck glang agley.

I widna care if it had ocht
Tae need a tender fitter's haund,
But it rins sae weel sin it was bocht
I hivna had tae slack a glaund.

I hate the tribe o' whurligeegs,
It's jist a pinch o' steam, then 'Scatt!'
I'm a receeprocatin' mon,
I stann or fa' wi Jeemie Watt.

—*Marine Review*

THE
ELECTRIC JOURNAL

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Starting a Large Railway Service

The electrifications of the Mersey Tunnel, and of the London Metropolitan Railway, as described in Mr. H. L. Kirker's article appearing in the May issue, and concluded in the current number of the JOURNAL, furnish striking examples of the wrong and the right way in which to start an entirely new service. The policy that will allow a thirst for display, or a desire to impress the public or stockholders to outweigh common sense and the advice of competent engineers as to the starting up of an elaborate and costly plant, cannot be too strongly condemned.

The contrast in the two cases described is doubtless more marked than would be likely in this country, or indeed outside of Europe, but attention to some of the obvious methods to be pursued is none the less pertinent at a time when numerous similar undertakings are in progress, or contemplated.

New York City furnishes several notable instances comparable to the Mersey and the London Metropolitan Railway, in which a change has been made from an existing to an entirely new system without inconvenience to the public, or strain upon operatives or equipment.

The Manhattan Railway, the elevated road of New York, was transformed from a steam to an electric line so gradually and smoothly as to be scarcely noticeable, except in respect to increased comfort of passengers, speed of travel, and augmented revenue. The same may be said of the Long Island Railroad, a part of which was electrified last summer.

The New York Subway was opened a year ago last November with full schedule by the Interborough Rapid Transit Company, and has been running ever since without a hitch, except when shut down by bursting water mains, or other causes beyond the control of the operating company. Before the opening of the underground road, however, all of which was new, the power house and sub-stations had been gradually put into operation, instruction trains run in the subway, and for about a week prior to the admission of the public, the full schedule of trains was maintained.

The large railroads entering New York City are at the present time engaged upon work of great magnitude, which, when completed, will enable them to do away with the use of the very objectionable steam service, substituting therefor multiple-unit electric trains and electric locomotives. It is to be expected that the change of motive power will be made with little or no disturbance or inconvenience. R. L. Wilson

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The Auxiliary-Pole Motor

The rapid development of industrial activity during the past few years is nowhere better exemplified than in machine shop practice.

Conditions of a few years ago have been very largely modified by two factors:

First, the introduction of high speed steels.

Second, the general application of the electric motor.

It is pleasing to note that, while in some instances the introduction of high speed steel has involved complications of a greater or less amount with belt driven machinery, the tendency of the electric motor at the present time is decidedly the reverse. The utilization of high speed steels to the fullest advantage involves the use of variable speed, and, while many attempts have been made to provide suitable variable speed mechanism for this purpose, the electric motor is rapidly supplanting mechanical devices.

Instead of line shafting and belting, with the consequent well known disadvantages, the tendency is now toward mounting the motors directly on the various machines. There seems at present to be a growing tendency to over-power rather than under-power machine tools. This is a decided step in the right direction particularly as there is no means of knowing whether high speed steel has yet reached its fullest development. The progress has been along natural lines in eliminating the complicated multi-voltage systems. The intricate wiring involved in these systems was quite as objectionable as the use of belting, though not so apparent.

The auxiliary-pole type of motor, described by Mr. Hipple in the May JOURNAL and in the current number, presents the acme of simplicity, together with remarkable operating characteristics. This motor has so thoroughly demonstrated itself, in every instance in which it has been applied, that we predict for it a very wide use. In the simplicity of its generating, distributing and translating devices, it presents a system which can be handled by operatives who are not expert in the electrical art: and the results accomplished in plants where the auxiliary-pole motor has been installed warrant the free use of this type of motor.

It might be mentioned in passing that in the case of the Firth-Sterling Steel Company, where a direct comparison between motor and belt driven machines was possible, it was found that the machines operated by auxiliary-pole motors produced in ten hours 46 per cent more than the belt driven machines. The auxiliary-pole motor is the result of careful and exhaustive investigation and the type of motor which is described by Mr. Hipple makes its appearance on the market as a fully developed and well-tried machine.

J. M. BARR

Benjamin Franklin

I have just finished reading the concluding installment of Dr. Edwin J. Houston's paper on "Franklin as a Man of Science and an Inventor," published in the April and May numbers of the Journal of the Franklin Institute.

We have all had a high opinion of Franklin as an electrical scientist and in other capacities, but personally I have never before had an adequate basis for such judgment.

This paper gives in Franklin's own words, which are most admirably put, example after example of his wonderful physical insight and eminently exemplary attitude of mind both toward science and toward the scientific fraternity.

I have profited from the reading of this paper, not only from a greatly increased respect and admiration of Franklin's ability as a scientist, but also from a stimulation of interest and a suggestion of methods, which is hard to get from any other source. Furthermore, I have received a considerable amount of new information and a clearer understanding of phenomena from his explanation than I have gotten from such literature of a later date as I have read.

I suggest to the readers of THE ELECTRIC JOURNAL the desirability of reading carefully this highly entertaining and profitable paper.

PERCY H. THOMAS

ON THE LAYING OF THE CORNER STONE OF THE ENGINEERING BUILDING

Why is the American professional man superior to his fellows in other countries? Because he is more democratic, more catholic, more open to conviction, a better mixer.

I am glad this is a union building.

The principle of union is as requisite and necessary in science as in politics and labor, and so long as there is unity among American engineers there will be greater achievement.—Andrew Carnegie.

The day of small things is past.

If we are to keep pace with the wonderful march of progress we must bore with a larger auger.

We need more than ever the conservation and uniting of all our forces for the accomplishment of great ends.

It is the scientifically educated engineer who must direct the immense establishments which from now on must be the rule.

He is necessary to prevent the waste both of capital and material.

Our national resources must be husbanded, not prodigally despoiled; our coal, iron and timber must be handled in the most intelligent way.

It will be largely with the members of these societies now united in this great building, to direct our great body of workers.

High minded leadership is the only salvation of our civilization.

This has been manifested by Mr. Carnegie, our benefactor. Through his generosity we may preserve and put in tangible form records of scientific accomplishments so as to avoid a repetition of mistakes of the past.—E. E. Olcott.

The Engineering Building

In the presence of Charles Haynes Haswell, now 97 years of age, the first engineer-in-chief of the navy, and of John Fritz, whose 80th anniversary was celebrated in 1902, whom we call "Uncle John—he is in science what Uncle Joe Cannon is in political life," in the presence of these venerable and worthy representatives of the engineers of the past, was laid the corner stone of the new building of the engineering societies, typical of the engineers of the future.

Mr. Carnegie has donated this building, not as a memorial for the past, not as a convenience for the present, but as an instrument for the future.

Steam and steel and electricity have introduced a new civilization. Engineering, as a force in progress, is becoming more and more essential, and more and more potent. To foster and develop it, to unify and strengthen it, to make it more powerful and more efficient—this is the idea which has brought forth this magnificent building.

The rate at which the electrical branch of engineering is advancing is significant. In the three years since the inception of this building the membership in the American Institute of Electrical Engineers has doubled. In a slightly greater period electrical enterprises, as measured by capital investment or in power output, have doubled; likewise has the number of electrical engineers necessary to conduct them. If the electrical activities of to-day were presented to the electrical engineers of five years ago they would be inadequate in numbers, in ability and in experience to operate them. Likewise, the demands five years hence will be for numbers, ability and experience which the present does not possess. The rate of progress will depend largely upon the rate of development of intelligent, effective men.

This is the problem of the school, the large corporation, and the engineering profession. The national societies are not fully alive to their opportunities, their possibilities and their responsibilities. The new building will give the incentive as well as the facilities for a wider activity and a greater usefulness, in harmony with the ideal which prompted the gift. CHAS. F. SCOTT

MECHANICAL AIDS TO COMMUTATION

J. N. DODD

THE subject of commutation is the most important one that concerns the designer of direct-current machinery, and one might say electrical machinery in general. If a machine does not commutate no slide rule calculations, no appeal to text books or other authorities, no recalibration of instruments, no use of the magic terms, power factor, inherent regulation, leading or lagging current will in any way convince the customer that his machine is perfect. It is a trouble for which the engine governor cannot be blamed.

Moreover, besides being easily seen and plainly visible to everyone, it is very serious trouble. If a machine hums, if its regulation is poor, if its efficiency is not up to guarantee, at least it will run and give good service. Nothing destroys a machine so quickly as poor commutation. If a machine overheats, we know that we must either decrease the losses or increase the ventilation. If the insulation breaks down, while we might blame the atmosphere and the running conditions, we know that things can be made right by better insulation or more of it. Almost every designer can tell how for a time he has been completely puzzled over the poor commutating qualities of some machines. Any of them can offer you instances of two machines apparently exactly alike, one of which sparks viciously and the other will carry any load or over-load that can be put on it. Moreover this inability of the designers to always locate the trouble at once is not due to want of attention on their part. No subject has received anything like the attention that this has. It is a most fascinating subject to study theoretically and practically a most important and pressing subject to get at at once and make right. Every year sees more articles on how to obtain sparkless commutation. Every year sees a long list of patents with the same object in view.

Originally it was a source of trouble to the direct-current designers only, now it belongs to all people, direct-current and alternating-current.

It must not be supposed, however, that we are making no progress with our knowledge of the subject. Five years ago it would have been deemed impossible to run at the speeds now run, or for a given speed to get the output from a given amount of material that we now do. The development of the direct-current turbo and the alternating-current single-phase motor are due directly to our better knowledge of the subject. Only it must be understood that a great deal remains yet to be done. The object of this paper is not to give anything new. The whole of it has already been covered by various patents. It is merely to define commutation and to explain the purpose and limits of the various devices meant to improve it.

COMMUTATION DEFINED

In its definition it is extremely simple. Let us have, Fig. 1, a number of bars of conducting material lying beside each other, but not touching. Let each be connected to the one on either side through a coil of conducting material, and let a moveable piece of conducting material rest on the bars. We will call this a brush. Let us also suppose that an electric current enters the series of coils at each end and comes out at the brush. If now the brush moves along the bars, the current in each coil will decrease to zero and then rise again to its full value in the opposite direction. In other words the current in each coil will reverse. This is the whole sum and substance of the commutation. That is, that the current reverses due to the moving of the brush. This is an explanation which everyone can understand and at the same time one will be able to understand to some extent that there are difficulties in the way.

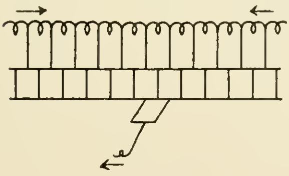


FIG. 1

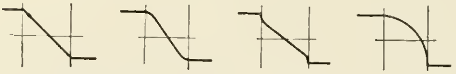
To a certain extent the title of this paper may be a misnomer. We will assume that our mechanical construction is perfect. The coils are continuous and homogeneous from end to end; all joints are perfectly sweated, the commutation surface is perfectly smooth and the bars rest evenly on the commutator, making at all times perfect mechanical contact.

Nevertheless the title will, we believe, suggest to most people the ideas intended, namely, the use of various materials in the circuit we have just considered, various shapes of the coil and the magnetic circuit.

POSSIBLE COMMUTATION CURVES

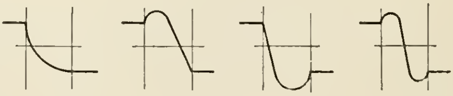
As to the actual phenomena of commutation we know very little. We know that before commutation the current in the coil has a certain value. After commutation it has the same value in the opposite direction. What we do not know is how it changes from one value to another, and this is the great thing of importance, for this curve of commutation is what tells one what is happening in a machine and what it is that causes poor commutation. However, although we do not know what this curve is in each case, we do know that certain causes will have certain effects. The curves of reversal shown in Figs. 2 to 9 are all possible.

These curves are plotted in terms of time and current value. The distance between the two vertical lines represent the time that it takes for the insulation between two bars to cross the brush and the vertical distance from the curve to the center line is the value of the current.



2, 3, 4, 5
FIGS.

Fig. 2 shows the whole time taken up in reversing the current. Figs. 5 and 6 show that the current hangs on and reverses in a very short time. That is, the effective width of the brush is not the whole brush, but only a very small part of it. The same for Figs. 3, 4, 7, 8, and 9. Figs. 7, 8, and 9 are especially interesting. The useful current in the coil is its value before commutation and is caused by conditions of the outside circuit. The rise of current in these three cases is due to some active electromotive force in the coil short circuited by the brush. This causes a current limited by the resistance offered by the coil, the brush and the brush contact surface. It is therefore an eddy current and may be especially harmful. Now the real cause of the bad effect of poor commutation when brought to its essence is too high a current density in some part of the brush or in some part of the commutator bar. This heats both bar and brush, eating away the brushes and roughening and pitting the commutator. From what has been said it will be seen that any departure from the straight line, Fig. 2, has the effect of making a thinner brush and therefore a higher current density. In fact, the steepness of the curve may be taken as a measure of the current density at any particular point. This is not necessarily the case when the steepness occurs at the center of the curve. Consider the case of a brush covering two bars or less, the steepness being at the center. In this case the worst that can happen is that half the brush carries the whole current, as the number of



6, 7, 8, 9
FIGS.

bars covered by the brush would increase the local density would also increase, but in any case, a curve perpendicular at the center would not mean an infinitely high density at the center. So long as the brush covers two bars or more the more the active surface will not be less than the surface of one bar.

If it is necessary to have a higher density at one part than another, the best place is at the center of the brush and following this the trailing edge of the brush. The worst place to have a high current density is the leading edge. The reasons for this are that the spark is usually pulled at the leading edge as at this point the brush and bar finally separate. A high density at the edge of the brush usually means a high density at the edge of the bar resulting in pitting this edge; and a high density at the center of the brush offers better opportunities for the brush cooling itself than if this occurs at one edge.

Therefore the shapes of commutation curves in order of their value are Figs. 2, 3, 6, 4, 8, 5, 7 and 9. Fig. 2 is the ideal commutation. Fig. 3 is very good. Figs. 7, 8 and 9 are usually exceptionally bad, though it is possible to have a certain amount of eddy current and get very fair commutation.

HIGH RESISTANCE BRUSHES

We are now in a position to consider how we can obtain these various curves. In the first place suppose that the brush moves very slowly, that there is no self-induction, or induction from any outside source, and that the resistance of the armature coil is zero, and that the only factor which we can consider is the resistance of the brush contact surface and that this is constant over the whole surface. In this case the current entering the brush from each bar depends upon the amount of the bar covered by the brush. That is, the current in the coil will vary from one extreme value to the other in a straight line, in other words, we have perfect commutation. It is possible to obtain equally good results by the use of a brush of varying resistance and carrying capacity which will cause curves of Fig. 3 or 6 without any of the objections to this style of curve, as the brush would be especially designed to take care of it. In general the only limit to the amount of current which we can commute in this way is the straight carrying capacity of the brush, and we can say that we will obtain perfect commutation with every machine if the resistance of the contact surface of the brush is infinitely high compared to the resistance of the coil and if we can arrange other forces so that they annul each other. The first of these conditions is, by the way, not an impossibility. For all practical purposes, we obtain it in almost every direct-current machine. Let us now suppose that the resistance instead of being in the brush contact surface should be in the armature coil, that is, the resistance of the coil should be infinitely high compared with the resistance of the brush contact surface. We would then get the case shown in Fig. 10. That is, the instant the brush touched a bar the current in the coil drops to zero until the brush leaves the bar. This is a case of extraordinarily bad commutating conditions. The whole current in the coil comes through a very thin piece of the brush. This burns the brush and burns the commutator. An approach to this condition is found in the use of copper brushes. With carbon brushes and the ordinary style of armature winding if other forces are absent the commutation curve varies very little from a straight line. With copper brushes it may vary considerably from a straight line.

HIGH RESISTANCE COILS OR LEADS

If we place the resistance in the armature lead our condition will be slightly different from the above. If the width of the brush is the same as the width of the bar our conditions will be the same as already shown in Fig. 10. If, however, the brush covers two bars, the condition will be as shown in Fig. 11.

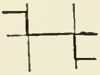


FIG. 10.

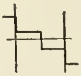


FIG. 11

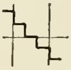


FIG. 12

Fig. 12 shows the conditions present if we have a brush covering three bars and as the number of bars increases the conditions will approximate the condition of resistance in the brush contact surface.

Under most conditions, however, the effect of high resistance leads is to make the edge of the brush, and therefore of the bar, carry an undue amount of current.

In a general manner we can say that if we can annul all other forces, the proper place to put high resistance is in the brush contact surface. A high resistance in the armature, either in the coil or in the leads, is a distinct evil. It is a detriment rather than a help.

In most machines the external forces acting on the short-circuited coil are small and we can obtain perfect commutation by means of high resistance brushes. We must, however, study the effect of the other forces which may enter. In the first place there is induction from the outside circuit. If, for example, the brushes are shifted back, the commutated coil will be under the influence of the field which is causing the current to flow through the armature. As has already been pointed out, the current which flows through the coils before they are commutated is limited by conditions of the outside circuit. While, if there is an active electro-motive-force in the short-circuited coil the current which causes it is limited by the resistance of the circuit in question, namely the resistance of the armature coil, the leads and the brush. In other words, the current in the coil will hold on in direction of value and will not reverse until it is compelled to by the high resistance of the small part of the bar covered with brush; that is, we will have commutation according to Fig. 5, or even according to Fig. 7. In the same way, if we rock the brush forward, we will obtain commutation according to Figs. 6 or 8.

EFFECT OF SELF-INDUCTION

Self-induction may be defined as electrical inertia. Its effect is to keep the current flowing in the same direction through the coil That is, its effect is to cause commutation according to Fig. 5. Also, self-induction will cause commutation according to Fig. 7, though the reason for this is not apparent at once. Self-induction is the force which tends to keep the current in a coil constant. How, then, can it increase the value of the current, especially in view of the fact that it does not come in force until the current begins to decrease? However that may be, experiments undoubtedly show that self-induction, if sufficiently bad, will cause commutation according to Fig. 9.

From these figures we can see the effect on commutation of that oldest and most common device, shifting the brushes forward. Self-induction, as we have seen, gives the curves 5 and 7. A forward lead to the brushes gives curves 6 and 8. The combination of these to 5 and 6, or 7 and 8, will, in a great many cases give a closer approach to the straight line commutation. The limitation of the benefits derived from this are just as plainly seen. The voltage induced in the coil by a forward lead is just as great whether there is a current flowing in the coil or not, so that if the load is removed and the brushes left in their forward position we will get at no-load commutation according to curve 10. Moreover the field strength is weaker at the point farthest from the field. If then, the self-induction be such as to cause commutation according to curve 7 the field will very often not be of sufficient strength to reverse the current at entering and entirely too strong to reverse the current in the bar which is leaving; as a result we will get commutation according to Fig. 9.

It is interesting at this point to study the effect of using a high resistance either in the lead or in the armature coil.

In the first place suppose we have self-induction only causing commutation according to curve 5. In this case we can easily see that high resistance leads are of no use, although they cause the reversal of the current to begin sooner and so force the trailing edge of the brush to carry some current, yet their effect on the extreme leading edge is to cause even a worse condition than we had originally. This will be seen by combining curves 5 and 4. Even if the self-induction is such as to cause commutation according to curve 7 the value of high resistance leads is questionable.

It must be kept in mind, however, that if we have the causes leading to curve 7 we will also need brush shifting, thus causing commutation according to curve 9. It is here that we see the value of the high resistance lead. Its effect may be seen by combining curve 9 and curve 4. Its tendency is toward perfect commutation. On the other hand its limitations are just as quickly seen. This tendency toward perfect commutation is at only one load and brush position. With a considerable change of load and with the same brush position the tendency toward eddy currents may be so great that the high resistance cannot keep them within reasonable limits.

Another objection is that in order to be effective the resistance of the high resistance leads must be a considerable proportion of the armature resistance. This lowers the efficiency of the machine and adds to the difficulty of cooling. The second of these is the more important of the two. If the resistance should mean an efficiency lowered by one per cent. or even two per cent. the lower figure being usually above the mark, it means only one or two per cent. in the steam consumption. This is of very little importance compared with getting a perfect commutating machine.

The second objection, the extra heat to be dissipated, will often give more trouble.

CHORD WINDING

A great deal can be done toward obtaining sparkless commutation by the use of chord winding. For the benefit of those who are not thoroughly conversant with all details of dynamo designs, a few words of explanation are not out of place. As is well known if we follow the coil of an ordinary drum armature we pass from the commutator to the armature core across under, it may be the middle of one pole along the back connection across the armature core under the middle of the pole next succeeding the one we had first passed under, back to the commutator. That is the angle between the two sides of the coil is as we usually consider it, the same as the angle between two consecutive poles. There is, however, no law, mechanical or electrical, compelling us to make the coil in this way.

So long as the two sides of the coil are never under the same pole at once there will be no serious effects. If we make the angle between the sides less than the angle between the poles we will usually make the cost of the coil slightly cheaper. When the angle between the sides of the coil is the same as the angle between the poles, the winding is called pitch winding. If it is otherwise, it is called chord winding, or fractional pitch. With pitch winding the direction of the current in the armature coil is as shown in Fig. 13, where in commutation one coil passes from points 1 and 6 to 2 and 5, and the other coil passes from 3 and 8 to 4 and 7.

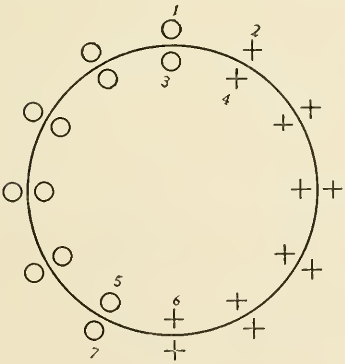


FIG. 13

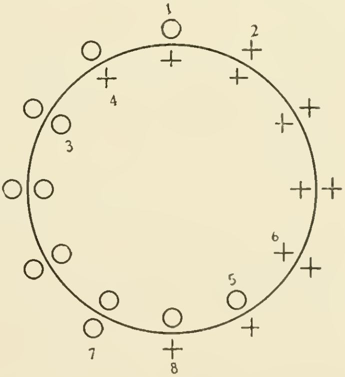


FIG. 14

If we have chord winding our condition will be as shown in Fig. 14, where 2 and 5 are the two halves of the coil.

We can see in passing the first advantage that if we have the same amount of brush shifting in each case, the distorting and demagnetizing effect of the armature will be less with the chord winding than with pitch in proportion to the ratios of the angle of the arc subtended by the coil in the two cases.

As a matter of fact the brush shifting is less with chord winding than with pitch winding. Consequently the demagnetizing effect of the armature is always less with chord winding and the distorting effect is usually less. This, however, is a point which affects the amount of materials used on the field coils not the commutation.

EFFECT ON SELF-INDUCTION

The effect of chord winding on commutation is very marked. In the first place the sparking due to self-induction is less. When a current flows through a conductor a magnetic field is set up around the conductor. If it is imbedded in an iron slot this field will be very much stronger. The form of the field will be as shown in Fig. 15. If the current dies away a voltage will be set up in the conductor due to the dying away of the magnetic field. If the current reverses its direction this voltage of self-induction will be doubled due to the disappearance of these magnetic lines and to their re-appearance in the opposite direction. It does not matter whether in a machine a set of lines surrounded each slot or if one set of lines surrounded all the slots on one side of the armature. The result in either case is the same. In chord winding the slot passes from a position where it is surrounded by a flux to a position where there is no flux, or vice versa, and with pitch winding it passes from a position where there is a flux to a position where there is a flux in the opposite direction, that is, with chord winding the self-induction is cut in half.

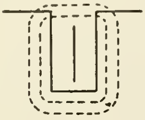


FIG. 15

It should be pointed out that to get the full advantage of chord winding the reduction in the coil span should be so great that the commutation of the upper coils in a slot must be entirely complete before the commutation of the lower coils shall have begun at the other brush.

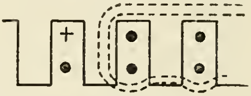


FIG. 16

EFFECT ON FIELD DISTRIBUTION

Many writers make the statement that to have good commutation we should have a wide neutral space between pole tips, so that commutation may take place in a part of the field free from the influences of the poles. Others maintain that the distance between pole tips should be short so that the coil will always be under the influence of the pole.

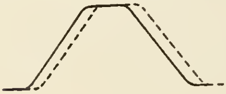


FIG. 17

Certainly with a wide distance between pole tips we will have the advantage of better ventilation and low leakage. If there is an advantage in having the tips close together the same advantage may be obtained with the tips far apart and the use of chord winding so arranged that as one side of the coil emerges from the pole the other enters.

To obtain perfect commutation we must keep down the value of the voltage between bars covered by the brush. Suppose one measure the voltage from a brush to each commutator bar and plot the results in a curve. The results we can call the voltage curve. With a wide space between the pole tips and a pitch winding or with a chord differing very slightly from the pitch the no-load voltage curve will be shown in Fig. 17. At full load, as we usually express it, the field is pulled over into the neutral space. As we usually conceive it the resultant full-load voltage curve is as shown in the dotted line Fig. 17. If this represents the actual conditions the contention of those who assert that the no-load curve should be as above are correct. As a matter of fact, however, the conditions are not entirely as shown in this figure. The full-load voltage curve is the resultant of two curves. One component is the no-load full voltage curve shown in Fig. 17. The other component is a curve of armature magnetization. The no-load curve is the curve due to the main field and lies directly across the armature from one main pole to another, the center of the field being coincident with the center of the main poles. The curve of armature magnetization lies practically at right angles to this curve, the center of the field being coincident with the line of the brushes. Therefore the curves are those shown in Fig. 18, where the full line curve is the curve due to the main poles and the dotted curve is the armature alone. The full load curve may be obtained by taking the sum of these two curves.

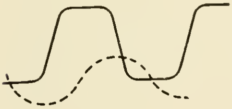


FIG. 18

This statement may be very easily proven. Take the voltage curve of any machine at no-load brushes neutral. Take again the voltage curve of the same machine full current full voltage brushes in the same position. The curve which when combined with the no-load voltage curve will give the full load curve may be obtained by plotting the difference between the two. It will be found to be a curve of the kind shown in the dotted line, Fig. 18.

This curve is, by the way, a constant over a very wide range of voltages.

This curve is usually steepest at the brushes. In order that the full-load curve may be approximately flat at the brushes, that is, we get zero voltage per bar, it is necessary to shift the armature magnetization curve, that is, shift the brushes to such a point that combined with the no-load curve we will get the flat condition desired.

We also see that for a machine with a wide neutral space if operated with brushes in no-load neutral position there is little to choose between the commutation at full-load, full voltage and full-load at a very low voltage. In certain classes of machines operation with the brush in this position is a necessity.

If now we use a narrow chord winding we can so adjust the angle of the chord that just as one side is emerging from the influence of the pole the other is entering. The voltage curve of such a machine will be an acute one, Fig. 19 having no flat portion corresponding to the neutral point.

By combining curve 17 with the curve due to armature magnetization shown in Fig. 18 we will get the full load curve. You will note that while this resultant curve is steeper at the trailing edge of the brush it is more level at the leading edge, where the spark is usually formed. Consequently the commutation would be better. We will be better able to follow this by considering the commutation curve. With a very narrow neutral space the trailing edge of the brush is in the back field, while the leading edge of the brush is in the forward field. Consequently the commutation curve due to field alone will be according to Fig. 3, and the full-load commutation curve will be found by combining Figs. 3 and 5, a combination which is much better than Fig. 5 alone and is without the disadvantage of the combining of Figs. 5 and 6, in that it is obtained without shifting the brushes. A combination which should be of great value is (a) a narrow span to the armature coil; (b) design the machine so that a great number of lines enter the armature from the pole so as to make a steep voltage curve directly at the brushes; (c) provide the armature with high resistance leads; (d) a thin brush covering preferably only one bar.

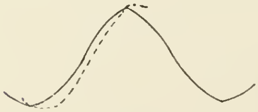


FIG. 19

LIMITING CONDITIONS

In this way it should be possible to obtain all the advantages of high resistance leads, and a great lead to the brushes without the disadvantage of having to shift the brushes.

In all the devices which we have so far considered the limits have been very easy to see, the limiting conditions are usually very soon reached and none of them will give perfect commutation at all loads and with a fixed position of the brushes.

A high brush contact surface is of value but it will give approximately perfect commutation only when the other forces are low.

High resistance leads are of value only when we have self-induction and a great forward lead to the brushes, or its equivalent. Chord winding, even with all the refinements we can suggest, a thin brush, high density in the air gap at the pole tips, and high resistance in the armature leads will merely have a tendency to straighten the curve at the leading edge. It will not straighten it over its whole extent at all loads. Moreover, high resistance is not altogether desirable. It introduces an undesirable amount of heat which must be dissipated and it lowers the efficiency. The high magnetic density in the air gap usually means also a high magnetic density in the teeth, causing a considerable armature heating. The thin brush entails a very long commutator, which for high speed machines especially brings in additional mechanical difficulties with what is already a most difficult part of the machine.

AUXILIARY COILS

As has already been pointed out in the first of the paper if we can eliminate all forces except the brush contact resistance, we will have the necessary conditions for perfect commutation. As was also pointed out, for all practical purposes the resistance of an armature coil may be considered as zero compared with the resistance of the brush contact surface. Therefore, if we can eliminate the other forces, that is, armature self-induction and induction from the outside magnetic circuit, or if we can provide means for their annulling each other, we will have in every machine the conditions for perfect commutation.

Induction from the outside circuit is in most machines induction from the main pole. It is a very simple matter to make the distance between the main poles and the chord of the armature winding such that the commutated coil is entirely out of influence of the main poles. It remains for us therefore to consider the other force, namely, self-induction. This is a matter which to a great many people is shrouded in a great mystery. It is worth our while therefore to go back slightly in order to place the matter in as simple a manner as possible.

We have already seen that if the area of the brush is ample poor commutation is caused by too high current density in some parts of the brush. It amounts to the same thing and if no clearer, is at least another way of stating it, to say that poor commutation is caused by too high voltage between bars covered by the same brush.

The only cause of voltage between two parts in electrical machines is that the conductor connecting the two points is cutting magnetic lines. These lines can come from only two sources. In the first place, the main pole. These we have just considered. The remaining source is the armature itself.

As the current flows through the armature conductors the effect is precisely the same as if the armature were surrounded by a coil of wire carrying an electric current, one end of the coil being at the positive brush and the other at the negative brush. Therefore the armature is itself a magnet. When a coil is commutated it is merely moved from one side of this magnet coil to the other. In doing so it passes across the part where the number of lines is greatest and a voltage is induced in the armature coil.

There is then nothing mysterious in the idea of armature self-induction. It is not a special voltage due to the reversal of the current. It is merely the voltage set up in the coil at time of commutation by the coil cutting the lines of armature magnetization. It is then this armature magnetization that we must annul. The usual method of dealing with this cause of trouble is to so design the machine that this number of lines is so small that the voltage induced by them is too small to cause sparking.

RYAN WINDING

One of the early attempts to seriously grapple with the trouble is the Ryan winding, which was brought out in the year 1895. In this winding the main poles were bridged across with a piece of iron. Imbedded in this were wires in series with the armature current. These wires were so arranged and connected that the current flowing in them was equal in value and opposite in direction to the current flowing in the armature conductors. The idea was to neutralize the armature magnetomotive force in the neighborhood of the brushes. There are two objections. It is an expensive method. Doing away with sparking makes heating the limiting condition in a machine. For most machines we have found other cheaper methods of reducing the sparking and making heating the limiting conditions. It is only with the advent of steam turbines and modern alternating-current, direct-current motor generator set requirements that we are again finding that commutation is the limiting condition. For these more difficult modern requirements the purpose aimed at by Prof. Ryan is the one which most manufacturers now seek to attain, though in a slightly different manner.

SPECIAL AUXILIARY POLE

A very clever modification of this idea was developed abroad.

Half way between the main poles is placed an auxiliary pole. This consists of three smaller poles side by side, see Fig. 20, the center one of which carries the winding of a very few number of turns. This winding is such that the flux caused by it is opposed to the flux caused by the armature winding. The purpose of the three poles is that the most of the flux caused by the armature winding will pass through the two side poles. Since this flux does not pass through the commutated coil it can do no harm. The coils in which commutation is taking place are covered by the central pole and only sufficient turns are placed on this to neutralize the winding nearest to the commutated coils. There is an error in this reasoning. In order to annul the flux at the commutated coil, we must supply sufficient ampere turns to annul the entire armature magneto-motive force. The case is that a coil, the inner part of which is wound non-inductively. There will be a flux at the center of this coil regardless of the fact that the center coils are annulled.

USUAL TYPE OF AUXILIARY POLE

Commutating poles or auxiliary poles in their usual form consist of a single piece of iron placed over the commutated coils. This piece of iron is wound with turns in series with the main current. The air gap, the shape of the pole, the direction of winding and the number of turns is such that flux due to armature magnetism is neutralized. The idea is not new. It was first suggested by Swinburne in 1891.

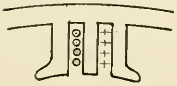


FIG. 20

There are, of course, a few difficulties. We must entirely neutralize the armature flux. For this it is not sufficient to supply as many turns as we have on the armature but we must supply more. In a machine without auxiliary poles the armature flux is the flux of armature self-induction. This flux lies across the slot and in the air outside the armature. There is also a self-induction of the armature end connections. If we place over the commutated coil the auxiliary pole without the winding we will have an additional flux due to the lower magnetic resistance of the path. An auxiliary coil of the same ampere turns as the armature will annul this additional flux, but will not decrease the armature self-induction. That is, sufficient turns must be placed on the pole so that no lines emerge from the armature due to armature magnetization. Moreover, at least enough must enter the armature at the pole to make up for those that emerge at the armature end connections.

In addition to having as many lines enter the armature due to the auxiliary coils as emerge due to the armature winding, the distribution must be the same, that is, it will not do if we first cut lines emerging from the armature and then an equal number of lines entering the armature, but at every instant during commutation the number of lines emerging from the armature must be equal to the number of entering lines cut by the commutated coil. In other words, for a given air gap one must have the correct number of turns and the proper shape pole shoe.

NUMBER OF TURNS AND SHAPE OF POLE SHOE

The number of turns and shape of pole shoes are matters which each manufacturer learns for himself.

Professor Niethammer, in the *Electrical World* of October 15th, 1904, says that the field ampere turns exceed the armature ampere turns by about 30 per cent. A very simple method of discovering the best number for any particular machine is to wind sufficient turns and shunt off till the proper number is discovered. The machine could then be left with a shunt permanently across these coils, just as a shunt is left across the series coils. If, however, one knows the voltage of self-induction of the machine it is a very simple matter to calculate the number of turns to be added. As for a practical means for learning the shape of pole shoe and number of turns, there are two methods of attacking the problem. One is by means of a wave tracer. With wave tracers connected to the armature coil so as to show the direction and intensity of current in the armature coil, one can obtain at once the curve of commutation. Instead of getting a pole shape which will give the curve of perfect commutation it is well to err slightly in the direction of Figs. 3 or 6. While this gives a slightly higher current in the center or the trailing edge of the brush it favors the leading edge where the sparking usually occurs.

When there are a number of coils in a slot, this wave should be taken for each coil in the slot and the pole shape chosen which will give the results which are best from a consideration of all. This method, however, usually presents difficulties.

Another more practicable method of discovering the proper shape and strength is to take a distribution curve of the machine, that is, the volts per bar in the vicinity of the brush and especially across the brush. This can be done either with an ordinary oscilllograph connected across two adjacent commutator bars or with an ordinary pair of finders, measuring the voltage between various pairs of points on the commutator distant from each other the thickness of a bar. The oscillograph is by far preferable. One usually obtains the best results by having the pole of such a shape and strength that we get zero volts between bars and one should err on the side of getting the pole too strong rather than too weak. The pole should be such that the trailing edge of the brush preferably but not necessarily is in the back field and the rest of the brush is in a zero or weak forward field especially the leading edge. In this way one will avoid a high current density at the edge of the brush and will concentrate it at the center.

WIDTH OF POLE

In order that the coil be under the pole during the whole of the time of short-circuit Prof. Arnold, in his address to the Electrical Congress at St. Louis, gives the length of the pole face as the thickness of the brush increased in proportion of the commutator diameter to the armature diameter with the proper correction for the number of coils in a slot.

CHORD WINDING

It is rather a shock to one to find that with auxiliary poles, chord winding is of no special benefit, but rather the reverse. It slightly reduces the number of turns on the poles.

On the other hand it complicates matters and takes away the flexibility.

Fig. 21 shows the two coils commutated simultaneously at the time when they are in their central position. Part of the coil should be under the influence of the pole continuously from the beginning of commutation to the end. To obtain this, the pole must be at least as wide as the distance between centers of the commutated wires. If it is less than this, part of the time of commutation the coil will not be under the influence of the auxiliary pole.

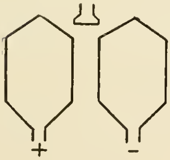


FIG 21

If it is desired to make the pole narrower than this, it will be very difficult to do so unless the distance between the coils is so great that the pole may be narrowed by taking a piece from its center. If the pole should be wider than the distance between the two wires we again come into difficulties, because if we make it wider part of the time both halves will be under the pole at once and we will get double the reversing force that we have the rest of the time. One advantage of chord winding may be noted. With chord winding first one-half of the coil is under the pole and then the other. The effective width of the pole is accordingly double what it would be with pitch winding. Since with auxiliary poles the ventilation is considerably restricted, this might be a considerable advantage. On the other hand we can not adjust the width at all and we can not alter the shape unsymmetrically.

LIMITS OF AUXILIARY POLES

As to the limits of the advantages of auxiliary poles, it is difficult at present to speak with certainty.

It appears for all time to make mechanical considerations and temperature rise the limiting factor in dynamo designs. As we have already said, on most machines we have already learned by other means to make these our limits. That is, commutation is not usually our limiting condition. It is only with the more difficult machines that we need at present consider it, that is with turbo generators, alternating-current, direct-current motor generator sets, variable speed and variable voltage machines.

The tendency of engine construction is ever toward higher speed and its consequently decreased floor space. We are learning more and more the advantage of ventilation and the greater output of machines which it entails, especially with the higher speed machines. It is not out of the way to predict then, that auxiliary coils will also come into vogue with engine type machines of the higher speeds. The degree to which they come in depends on the efficiency of our ventilation. Comparatively speaking, however, their use will be limited.

THE LUBRICATION OF BEARINGS

A. M. MATTICE

AS the successful operation of machinery depends in large part upon the ability of the bearings to run continuously without undue friction and wear, the proportions and details of the bearings demand the utmost care on the part of the designer. In the present article I will not touch upon the matter of the proper proportions of bearings for various conditions, but will confine my remarks to a few practical observations on lubrication and features incident thereto.

In a great many cases bearings give trouble, although the surface velocity and pressure per unit area are well within safe limits, and although proper lubricant is applied in ample quantity, the troubles being caused by the lack of attention to small, but essential details.

One of the commonest causes of trouble in two-part bearings is side binding. This occurs principally in vertical engines and in other machinery where the principal load on the bearing is that due to the dead weight of the rotating part. The bearing boxes are too often bored and scraped to a good fit all around without being eased off to prevent wedging action near the parting of the boxes. This not only causes a tremendous pressure on the bearings at these points, but prevents the oil from getting in between the shaft and the bearings. A bearing is always much better if eased off so that it will be well clear of the shaft for at least 20 degrees of arc on each side of the center line, and even 30 degrees is not excessive. Many designers, especially those who have not had practical experience in the operation of machinery, seem to dislike to lose any part of the bearing area by easing off the sides of the boxes, but area at these points is more detrimental than efficient, and bearings which are originally made with all around contact can frequently be improved by the use of hammer and chisel.

Let the oil have a fair chance to get in its work. The edges of the bearing boxes are frequently left sharp, thus scraping off the oil instead of assisting it to enter. If the box is eased off to form a channel for the oil, meeting the shaft approximately on a tangent, oil will be drawn in instead of being scraped off.

OIL GROOVES

In the matter of oil grooves also, designers frequently seem loth to sacrifice bearing area, apparently losing sight of the fact that no area, no matter how great, can be sufficient unless properly lubricated. Oil grooves should be large, arranged so as to keep the oil well distributed, and should have the edges well rounded off to facilitate the entrance of oil between bearing and journal. The simple removal of the sharp edge of the groove is not sufficient. Too many designers, moreover, seem to look upon the matter of oil grooves as of too little importance to be worthy of their consideration, but rather something to be left to the shop to take care of, or to be neglected entirely. The result frequently is an oil grooving which does more harm than good, leading the oil to certain parts of the bearing and leaving other parts dry.

METHODS OF LUBRICATION

In the days of slow moving machinery it sufficed to use tallow or pieces of pork-fat, placed in openings in the bearing caps and resting directly upon the shaft. As machinery grew heavier and speeds increased, the necessity for some more efficient means of lubrication made itself felt. It was known that oil was a good lubricant, but there was the difficulty of applying it in some automatic manner without waste.

Finally some genius hit upon what in its day was considered the acme of perfection in the matter of lubrication—feeding oil by means of wick siphons. A number of holes in the bearing cap connected with the oil reservoir above the level of the oil. In these holes were placed wicks, dipping in the oil. The rate of feed was regulated by the number of wicks or the number of strands in each wick.

It was not so very long ago, either, that these primitive methods were the only ones in vogue. When I first went to sea, some thirty-three years ago, the only methods of lubrication were wicks for the engines and tallow for the line shafts. The introduction some years later of adjustable drop-feed oil cups was a marked improvement, followed later by the addition of "sight feeds," so that the attendant could see what was going on, instead of increasing or decreasing the feed according as the bearings felt too hot or otherwise.

IMPROVED SYSTEM OF LUBRICATION

From time to time various systems of improved lubrication have appeared, such as ring oiling, chain oiling, felt pads, packed waste, compression and spring grease cups, etc. But with the exception of the "splasher" system, which is very efficiently used in a number of types of enclosed engines, the old type of drop-by-drop lubrication, feeding the oil in homeopathic doses, is the one most generally used with engines, although it is about the least efficient and most expensive method of all.

The smaller the amount of oil fed to the bearings, the more it costs. This at first seems paradoxical, but it is true for the reason that if just enough oil is fed to the bearings to permit of motion without damage, the oil becomes "worn out" by excessive friction. If on the other hand an excess of oil is supplied, a less quantity is actually worn out, while the excess can be recovered and used over again.

This old system of drop-by-drop lubrication is not only wasteful, but it leads to danger of cutting the bearings by reducing the oil supply to a dangerous minimum. It is not altogether the fault of engine builders that this form of lubrication is the one most generally used by them, but rather because purchasers will not stand the slight additional first cost of a better method.

Ring oiling and kindred systems are very efficient for a large class of bearings, but unfortunately are not well adapted to engine work, especially in large sizes, although some designers have done some very good work along this line. Ring oiling, however, is admirably adapted to many forms of electrical apparatus, and is probably used to a greater extent in that class of machinery than in any other.

Grease and similar lubricants have their limitations, but are ideal lubricants for many purposes, and in engine work can be used to good advantage on the smaller parts of valve gear, and even on eccentrics.

Supplying oil under pressure is a necessity with step bearings which carry very heavy weights, and has been applied with success to horizontal bearings where the work is extremely heavy; but this class of lubrication may be considered as adaptable only to special cases where it is an absolute necessity, to be avoided if possible.

CENTRAL GRAVITY SYSTEM OF LUBRICATION

The central gravity system of lubrication, which has come into extensive use in engine installations within the past few years, has resulted in a marked saving in cost of lubrication and the elimination of bearing troubles, and the details of such systems are well worth the serious attention of engineers. I refer to the systems which, while varying in details, comprise essentially an overhead supply tank, pipes leading to all bearings with valves for regulating the supply, arrangements for catching the overflow oil, settling tanks, filters and pumps for returning the oil to the supply tank, the whole system being automatic, and resulting in a continuous circulation of oil. Although this system is at present used principally in large installations, it has been used with success in smaller plants and I believe that engineers would be fully justified in using it in installations of single engines of large, or even moderate size. Its success is not only due to the saving of labor, as in large installations, but by supplying an excess of oil to the bearings the oil does not become "worn out" as in the drop-by-drop system, thus resulting in a reduction of oil bills.

FLOODED SYSTEM OF LUBRICATION

A further extension of the principle of continuous circulation of oil obtains in the flooded system of lubrication which has come into use in connection with steam turbines. In fact, this system was introduced by Parsons before the central gravity system for reciprocating engines came into vogue. This system consists in supplying to the bearings as much oil as will flow through them; the oil carrying away the heat of the bearings and being cooled in a tubular cooler before going back to the bearings again. The oil is not forced into the bearings under pressure, but simply supplied at a head of from a few inches to several feet—just enough to allow it to flow freely to the bearings. As the oil is nowhere exposed to the outside air, circulating only in a closed system, it collects no dirt and does not need to be filtered, but is used over and over again continuously, the entire oil supply circulating through the bearings every few minutes.

By means of this flooded system speeds and pressures are used which would otherwise be impossible, and, what is of still greater interest to the owner, the oil consumption is reduced to a minimum. As instances of this I would cite the cases of two installations of 400 kw steam turbines of the Parsons type running at 3 600 revolutions per minute, one of which used only 50 gallons of oil in six months and the other one 55 gallons. At another plant one turbine of 400 kw and another of 750 kw, used only three barrels of oil in sixteen months. In another case two 1 000 kw turbines used one-half gallon of oil per turbine per week.

Some months ago I crossed the Atlantic on the turbine steamer "Virginian", and upon inquiring about the consumption of oil, I found that no oil had been added to the supply during four successive round trips, and the original supply had not appreciably diminished. The service tank contained a little less than 150 U. S.

gallons, and this was being circulated through the bearings at the rate of between 40 and 50 gallons per minute, the whole supply being circulated in less than every four minutes.

In the case just cited the oil referred to was that for lubricating the bearings of the three turbines. The line shafting was lubricated by the old drop-by-drop method, and used up a considerable quantity of oil, whereas the more exacting needs of the turbines themselves were met by the waste of practically no oil at all.

As another example, the turbine steamer "Queen Alexandria", which in the summer season makes daily trips on the Clyde, used less than one barrel of oil during a season of between four and five months.

Users of engines and other machinery would do well to take a lesson from the results of steam turbine lubrication, which has demonstrated beyond a doubt that the supply of oil in large excess of that actually required to prevent bearings cutting is in the long run the most economical, and far in advance of the old drop-by-drop method.

TEMPERATURE OF BEARINGS

Another matter upon which a few words may not be amiss is that of the temperature of bearings. There seems to be a wide misapprehension as to what is a safe temperature. I believe that much of the idea about safe temperatures is an inheritance from the time when lubricating oils were all of animal or vegetable origin and is not applicable to the high-test mineral oils of today.

Some time ago I happened to get into a controversy as to proper bearing temperatures, the immediate cause of which was an engine whose main bearings ran at a temperature of about 135 degrees F., while the owner claimed that a temperature of over 100 degrees was unsafe and produced "expert" testimony to that effect. Knowing from experience that this view was not correct, but requiring testimony to the contrary, I proceeded to have examinations made of the temperature of bearings of a large number of engines of various makes. The result of this investigation showed more large engines running with bearings at temperatures over than under 135 degrees. Many bearings were running at over 150 degrees, some considerably higher, and in one case a continuous temperature of 180 degrees was found, and in all of these cases the bearings were giving no trouble.

LEMUEL BANNISTER

CALVERT TOWNLEY

THE death of Lemuel Bannister, at the Hotel Imperial, New York City, on April 13th, from cancer in the throat, takes away a man as widely known and loved as any who was connected with the earlier years of the Westinghouse interests.

He first became connected with the Westinghouse interests in 1887, as vice-president and general manager of the Fuel, Gas and Electric Engineering Company, coming to them from R. D. Wood & Co., of Philadelphia.

He entered the Westinghouse Electric & Mfg. Company in 1890, as vice-president and general manager, and, later, on the expansion of that corporation, was made first vice-president.

LEMUEL BANNISTER.

His was the steady hand that never left the tiller during the troublous financial tempests of that time, and his the unruffled composure that met every difficulty with a confident smile that declared the battle half won.

The close of the year of his advent saw the storm's abatement, and during the next four years Lemuel Bannister put his untiring energy into the upbuilding of that great industry.

In 1895 the scene of his labors was transferred from Pittsburg to New York, and in 1897 on to London. Thenceforward American business knew him no more, but the reorganization of the British Westinghouse Company on a larger and a higher plane, of the French company, the beginning of the German company, and the laying of the foundations for other companies bear eloquent testimony that there was no abatement to his initiative or unceasing energy.

In 1902 he retired from active business, and severed his official connection with the various Westinghouse companies. He held at that time the title of first vice-president of the Westinghouse Electric & Mfg. Company. He was a member of the executive committee of the British Westinghouse Electric & Mfg. Company, Limited, and a director of the French company. Since then his residence has been in Paris, and his old friends on this side have had to be content with infrequent visits.

Lemuel Bannister had an intense humanity. His personal interest in the lives and loves of those about him was as keen as it was sincere, and they reciprocated with a personal loyalty that years of absence have failed to dim. The "Old Guard Dinner" was one expression of this feeling, when those who were with him in his early Westinghouse days gathered to do him homage at a loving banquet during one of his American visits in January, 1904, an occasion never to be forgotten by the participants, rich in reminiscences, and unique alike in its genuine sincerity and the mutual pleasure of the hosts and their guest of honor.

Physically robust, Lemuel Bannister defied fatigue, and clung tenaciously to his work, even when ill. Prostrated for many weeks in Philadelphia, in 1893, with a dangerous case of blood poisoning, he discharged his official duties from his hotel bed-room, and directed affairs at Pittsburgh over the long distance telephone, while flat upon his back.

He was tenacious of purpose, yet patient even in the face of exasperating opposition. His way was to win by logic, and by the overwhelming force of being right, combined with a suave diplomacy that never failed to win respect and liking, even from his bitterest opponents. Good natured, of an even temperament, a ready talker, and blessed with a good memory, his many interesting experiences made him a jolly comrade.

"Banny" is gone, but his indelible mark is on the electrical development of his time, is on the great corporation for which he strove, and on the hearts and lives of all his "boys."

THE MERSEY TUNNEL AND THE LONDON METROPOLITAN RAILWAY ELECTRIFICATIONS—II

H. L. KIRKER

THE electrification of the Metropolitan railway, London, affected half the Inner Circle and sixteen miles of the suburban line running north from Baker Street station. The "Distric Railway" electrification took care of the rest of the Circle. Two miles of the Metropolitan suburban branch and most of the Circle are underground tracks. Both companies' trains traveled over the entire Circle. In addition to these trains, there were numerous trunk line ones that had running rights over certain sections of the Circle. To successfully accomplish the object of the electrification, all the steam locomotives had to be eliminated from the underground service. An arrangement was arrived at among the various companies concerned, and the Metropolitan and the District Railways proceeded to carry on the work of electrifying the Circle simultaneously, but the electrification was at the best a complicated undertaking. We are considering here the Metropolitan and are concerned with the "District" only to the extent that the two services overlapped on the Circle.

The initial work on the Metropolitan consisted of a 15 000 hp central station, nine sub-stations, electric trains and locomotives in proportion. Five of the sub-stations were on the Circle, the others and the power station were out on the suburban line. The building and the equipping of the power station and sub-stations and the equipping of the rolling stock was in the hands of one firm. The railway management co-operated with the contractor in the execution of the work and in the program for the initiation of the new service. As the work progressed the railway company commenced to build up its operating crew. This brings me to the point I want to emphasize, namely, that as soon as we commenced preliminary running, these railway men were turned over to us, and I had as much authority over them as if they were on my own pay roll. This arrangement was made voluntarily by the Metropolitan manager. He was looking forward to the time when his men would have to operate the plant without assistance. He wanted, when that time arrived, to have an operating force trained to concerted action.

Everybody that was concerned in this working arrangement was advised accordingly.

The program was simple. Step by step the various units in the power station and sub-stations were set in motion and one by one the trains were tested out. As soon as sufficient units were available a few steam trains were taken off the suburban branch and a limited electric service inaugurated. As more units became available the steam service was further reduced and the electric service correspondingly increased until the scheduled suburban service was attained. The construction work on the Circle was so handled that the two companies started a limited service on the Circle at about the same time, and this service was then brought up and scheduled in the same way that the suburban branch service had been. There was no division of responsibility, the contractors were in full charge of the electric operation, the railway men did the work. The staff was increased as the train service was augmented, and our supervision diminished as the men became familiar with their work. Eventually our supervision disappeared and the responsibility was then transferred to the railway company. A brief reference to the more important events will illustrate the general policy followed.

The usual official inspections were made and there was systematic advertising, but nothing spectacular was attempted. In October, 1904, an exhibition run of the first turbine was made for the board of directors, and during the next month school trains were operated. In December the second turbine was put into commission and an official run made on the entire suburban branch. This was a formal affair. There were many representative railway and newspaper men among the guests. The banquet, trial run and inspection occupied an entire afternoon and passed off without a hitch.

On January first, 1905, the electric service was inaugurated on the suburban line. The traffic department had wanted an all-day, nine-train service at the outset, but the railway management deferred to the contractor's judgment, so the initial service consisted of three electric trains running ten hours per day. Later in the month more electric trains were substituted for steam ones and during the next month the daily operating period was extended. In March the third turbine was put into commission and an all-day service begun. At the same time the responsibility for the suburban sub-station operation was transferred to the railway company. A month later we relinquished the supervision of a considerable portion of the ordinary power station routine.

As soon as the work on the Circle had advanced sufficiently to allow preliminary runs a formal trip was made on this, the main part of the system. The Circle sub-stations were completed, tested and turned over to the railway company. On July first a limited service was inaugurated on the Circle. This was added to by both companies and the electric locomotives were finally put on. During September the load on the whole system attained the normal for which the power plant was intended. The system was now in full swing. The Metropolitan staff were practically doing all the operating. There was now no further occasion for the contractor to assume the responsibility, so in October it was formally transferred to the railway company.

Thus slowly but surely the electrical service replaced the steam service in a complicated system. There was no strain. The transition was made almost imperceptibly. There was little that was sensational during the transition period. The few incidents that did occur would not have been considered extraordinary in the normal operation of any railway plant. There were some troubles at the power station, but only one of these had a serious effect on traffic. This occurred after the plant had been in operation for some months. One unit was carrying the entire load. There was a sudden necessity to change over to another unit. Some of the operators became flurried and damaged slightly the condenser air pump belonging to one of the spare units. Leaving this machine they tried the next and damaged it also. In the meantime the fault in the turbine governor gear, which had caused the shut-down, was being repaired and this turbine was finally gotten in service again, after a suspension of the entire train service for twenty minutes. In the sub-stations there were but few incidents, a transformer short-circuited, an armature burned out, a brush holder grounded and several cables failed, but none of these had more than a momentary effect on the train service. There were some delays to traffic due to trouble with the rolling stock, but this was not of a nature that could be charged to inexperience on the part of the staff.

While we were completing the initial plant, instituting the new service and breaking in the railway company's staff we commenced the installation of an additional unit at the central station. This unit with its boilers, condensers and switch gear was available for service soon after the original plant was transferred. The Metropolitan company now being in full charge of the plant, there was no occasion for us to supervise the operation of the additional unit so it was transferred to the railway company as soon as the trial run was made on it.

At the yearly meeting the board of directors expressed itself as highly pleased with the smoothness with which the electric service had replaced the steam. The results were equally gratifying to the contracting company. That the results were satisfactory is not surprising. They were the logical outcome of the method pursued.

Now a word or two of comparison in the two cases we have been considering. The Mersey was a comparatively simple, self-contained system, but the railway company taking matters in their own hands, attempted, contrary to the contracting firm's recommendation, a complete electric service at the outset. We have seen how disappointing the results were. The Metropolitan was an extensive part of a complicated group of roads, and that its steam service could be replaced by an electric one without a minute of mishaps was not generally expected. We have seen, however, that the railway company co-operated with the contractor, that there was no division of responsibility, that the transition was made step by step, and that the net result was all around satisfaction. This brings me to my conclusion, which is this, that the substitution of an electric service on a steam road can be made a simple problem if the program is taken in hand early in the construction period and the co-operation of the railway company secured in a gradual change over.

THE CALCULATION OF THE ELECTRO-MOTIVE-FORCE INDUCED IN TRANSMISSION CIRCUITS

METHODS AND CONSTANTS FOR DETERMINING THE ELECTRO-MOTIVE-FORCE OF MUTUAL INDUCTION AND OF SELF-INDUCTION IN PARALLEL CIRCUITS

CHAS. F. SCOTT

IN a preceding article* the fundamental physical relations between current, the field produced by the current and the electro-motive-force induced by the field in parallel circuits has been treated.

It was shown that current flowing in a wire produces a magnetic field surrounding the wire, the density of which, outside of the wire, varies inversely as the distance from the center of the wire.

It was found that the total field between the surface of the wire and other wires may be represented by a curve, which is the logarithmic curve, and which possesses a number of important characteristics. The field lying between two wires parallel with the current-carrying wire is proportional to the logarithm of the distance to the more remote wire minus the logarithm of the distance to the adjacent wire. Now the difference between the logarithms of two numbers is equal to the logarithm of their quotient. Therefore, the field, and consequently the electro-motive-force also, which are induced in a circuit consisting of two parallel wires by current in a conductor parallel to them are proportional to the logarithm of the ratio of the distances of the two wires from the current-carrying wire.

If there be a second current-carrying wire it will likewise induce in the secondary circuit an electro-motive-force which is likewise proportional to the logarithm of the ratio of the distances of the wires of the secondary circuit from the second current-carrying wire. The total electro-motive-force in the secondary circuit is equal to the sum of these two electro-motive-forces. Now the sum of the logarithms of two numbers is equal to the logarithm of their product. Therefore, the electro-motive-forces induced in a secondary circuit by current in two current-carrying wires is proportional to the logarithm of a single number, which number is obtained by suitable division and multiplication of the distances between the several wires.

In order to find the electro-motive-force induced in the secondary circuit by current in the primary it is necessary, therefore,

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*The Electric Journal, February, 1906, page 81.

(1) to find a number which is a certain function of the distance between the wires;

(2) to find its logarithm, and

(3) to multiply this by a constant which applies to a particular strength of current, length of circuit, and frequency.

One wire of the secondary circuit may itself be a current-carrying wire. The electro-motive-power induced in such a circuit by the current in one of its own wires (not taking into account for the present the current in the separate return conductor) consists of two parts, first, that due to the field lying outside of the current-carrying wire, and second, that due to the field inside of that wire.

This case may be conveniently analyzed by employing an auxiliary wire as a part of the secondary circuit in place of the current-carrying wire. If the auxiliary wire be very small and lie at the surface of the current-carrying wire then the field included in the secondary circuit is that external to the current-carrying wire and is proportional to the logarithm of the distances of the two secondary wires from the center of the current-carrying wire. One of the distances is its radius. Now if the auxiliary wire be moved to the center of the current-carrying wire the field included in the secondary circuit will be augmented by the field within the current-carrying wire, which, as shown in the preceding article, is for a given current independent of the diameter of the wire.

If the current-carrying wire (instead of the small wire at its center) be made one side of the secondary circuit, the electro-motive-force is likewise due both to the field outside of the wire and to the field inside of the wire. The field outside of the wire has the same effect in the two cases, but the field inside of the wire is less effective when the current-carrying wire is a part of the circuit, for the reason that different portions of the wire are unequally affected. The central portion of the wire is affected by the whole internal field, but elements of the wire near the surface are not affected by that portion of the field which lies between them and the center. The resultant effect will be taken as that produced at a point located at a distance from the center equal to 0.7 of the radius, since one-half the area of the wire lies within this distance and one-half without. Between this point and the circumference there is also 0.5 of the internal field. Therefore the effect of the internal field upon the electro-motive-force induced, when the current-carrying wire itself is a part of the secondary circuit, is one-half of that produced when a separate wire at the center of the current-carrying wire is substituted for it as a portion of the secondary circuit.*

The area representing the internal field is a triangle. If the radius be 1 and the strength of field at the surface of the wire be 1, then the area of the triangle is 0.5, and half the area is 0.25. This is to be added to the external field, which is expressed by the logarithm of the distance to the second wire divided by the radius of the current-carrying wire. The expression for the total electro-motive-force therefore includes two terms, one containing a logarithm, the other a constant. It is desirable to reduce the two to a single term, preferably to the same form that has been developed for mutual induction.

This may be done as follows: Let the radius of the current-carrying wire be 1. Replace this wire by a smaller wire. The field external to the smaller wire will be the same beyond the distance 1 from its center as the field produced by the original wire. There will be a field between its surface and the distance 1, the amount of which depends upon its radius. Let the radius of the smaller wire be such that this amount is just equal to the effective internal field of the original wire. This is the case when the radius of the smaller wire is 0.78 of the radius of the larger wire. Therefore, the total effective field (both internal and external) of the original wire may be found by determining the field external to a wire which has a radius equal to 0.78 of the radius of the original wire. The latter may be expressed in the desired form, namely, a single term involving a logarithm. Thus, the field producing an electro-motive-force in a circuit, one side of which is a current-carrying wire, is proportional to the logarithm of the quotient of the distance to the second conductor divided by 0.78 of the radius of the current-carrying wire.

If, likewise, the second side of the circuit carries the return current the electro-motive-force is twice as great. This is obviously the ordinary case of self-induction, in which an electro-motive-force is induced in a circuit by current-flowing in that circuit.

The foregoing relations are set forth in the accompanying Fig. 1

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*In a preceding article, page 88, second paragraph, in which the physical relations between self induction and mutual induction are discussed, it is stated that the electro-motive-force of self induction in a primary circuit is "equal" to the electro-motive-force of mutual induction in a secondary circuit which occupies the same position; i. e., at the centers of the current-carrying wires. While self induction, as pointed out, may be considered as a particular case of mutual induction, yet the electro-motive-forces in the two cases are not exactly equal for the reasons set forth in the present article.

and the table. *A* and *B* are current-carrying wires of the primary circuit, *C* and *D* are wires parallel to them.

In the first three cases *D* and *C* constitute the secondary circuit, which is independent of the primary wires.

In the next three cases *A* is a current-carrying wire and also a part of the secondary circuit.

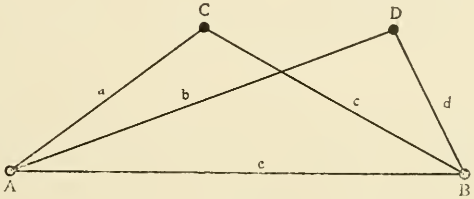

FIG. I

In the last three cases the two primary wires are likewise the secondary circuit. The latter condition may be derived from the first by assuming *C* moved to *A*, and *D* to *B*; then *a* becomes 0.78*r* where *r* is the radius of *A*, *b* and *c* becomes equal to *c* and *d* becomes 0.78*r*. In each case the electro-motive-force is proportional to the logarithm of a ratio.

TABLE

This table gives the logarithm to be used in order to find the e. m. f. induced in various arrangements of secondary circuits by current in *A* or in *B* or in *A* returning by *B*.

(1) Current in A; e.m.f. in C—D; log. $\frac{b}{a}$

(2) Current in B; e.m.f. in C—D; log. $\frac{c}{d}$

(3) Current in A & B; e.m.f. in C—D; log. $\frac{bc}{ad}$

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(4) Current in A; e.m.f. in A—D; log. $\frac{b}{0.78r}$

(5) Current in B; e.m.f. in A—D; log. $\frac{e}{d}$

(6) Current in A & B; e.m.f. in A—D; log. $\frac{be}{0.78\,rd}$

(7) Current in A; e.m.f. in A—B; log. $\frac{e}{0.78r}$

(8) Current in B; e.m.f. in A—B; log. $\frac{e}{0.78r}$

(9) Current in A & B; e.m.f. in A—B; 2 log. $\frac{e}{0.78r}$

In case (3) which is the general case, it will be noted that the two distances (b and c) in the numerator involve all four wires; also the two distances in the denominator (a and d) involve all four wires. If in any case the value of the number of which the logarithm is to be taken is less than unity, the reciprocal may be taken for convenience without affecting the numerical value of the result (although the sign changes, but that is of no consequence for present purposes).

The logarithm may be found from a table of logarithms or from the slide rule.

The constant by which the common logarithm is to be multiplied in order to determine the induced electro-motive-force is given below:

Frequency.	Current.	Length of Circuit.	Constant.
25	1	1 000 Feet	.022
25	1	1 Mile	.116
60	1	1 000 Feet	.0528
60	1	1 Mile	.279

The similarity between the constant .0528 and the number of feet in a mile may be an aid to memory.

A recapitulation gives the following method of finding the electro-motive-force induced in various cases of parallel circuits.

1. Find the distances between the current-carrying wires and those in which the electro-motive-force is induced, including in certain cases the radius of the current-carrying wires; then find the quotient corresponding to one of the nine cases above given. If the quotient is less than unity it is more convenient to use its reciprocal.

2. Find the common logarithm of the quotient either from a table of logarithms or from the slide rule.

3. Multiply the logarithm by the constant applying to the proper frequency for unit current and length of circuit; multiply by the actual current and length. (The electro-motive-force is directly proportional to current, length and frequency.)

THE AESTHETIC VERSUS THE ECONOMIC VALUE OF NIAGARA FALLS

THE fate of Niagara Falls under a continuing development of electric power has become a question of national importance. The Outlook for May 19th contains some interesting arguments from both the aesthetic and the industrial points of view.

The aesthetic side is presented by the Outlook in its editorial columns.

Mr. H. W. Buck, electrical engineer of the Niagara Falls Power Company, gives an excellent presentation of the claims of those who believe the industrial value of the Falls is more important than their purely sentimental value. We reprint from both.

NIAGARA FALLS FROM THE AESTHETIC STANDPOINT

The increasing regard in America for aesthetic and sentimental values is something with which law-makers now have to reckon and to which the spirit of commercialism has already been forced to yield. The Outlook heartily believes in the preservation of Niagara Falls as a great scenic feature of the country.

Is the prime object of a man or of a nation to amass all material wealth possible by the cheapest methods inventable? Or have beauty, imagination, poetry, painting, and music, which spring from wealth of the spirit, any demand upon us which we are bound to supply?

If there were any marked tendency of the American people to neglect material welfare for the pursuit of aesthetic beauty, it might be very well to call public attention to the fact that a hundred millions of dollars run to waste every year over the crest of Niagara Falls. But, as a matter of fact, the tendency has been during the last two centuries quite in the other direction. We do not need to be urged to make money out of our natural resources; we do need to be urged to protect some of our natural resources from the corroding and destructive side of money-making. It is an economic waste for a man to spend his time and money in growing a rose garden in front of his house—cabbages and potatoes pay better; or to put a beautiful Persian rug on his library floor—linoleum can be washed more easily and costs less. But it is not a real waste to collect and possess these objects of beauty.

No man has a right to spend more money on things of beauty than he can afford; no village ought to construct and maintain a public park when its school-house is in an unsanitary and tumble-down condition. But, fortunately, this country can very well afford not merely to maintain its parks, its public waterways, and its mountain preserves, but it can afford to add to them.

To our mind, the controversy over Niagara Falls is one of the most important of its kind that has ever demanded public attention in this country, since it is a test case. When the case is thoroughly understood by the people at large, we have every confidence that they will quietly and calmly decide to preserve Niagara Falls from the encroachments of commercial industry, and will devote themselves, if necessary, with scientific skill and patience to the discovery of some other means of supplying the cheap economic power which we trust some day will make electric lighting and street-car travel and useful manufacturing much more general and much less costly than the managers of the Niagara power companies have been able or willing to make them.

NIAGARA FALLS FROM THE ECONOMIC STANDPOINT

H. W. BUCK,
Electrical Engineer of the Niagara Falls Power Company

There are two sides to every question, and the recent outcry from all quarters of the country against the use of Niagara Falls for power purposes may be considered as the expression of opinion only from those who look upon Niagara Falls as a national spectacle, and who consider that its only value to the nation can be represented as such. It is quite natural and proper to regard Niagara Falls from the sentimental and scenic standpoint, for it had been so regarded for many years before it became a national industrial asset of great economic importance. The protest against its use for the development of power has been embittered by the erroneous belief that the capitalists who have developed the power of the Falls have been the only ones to derive benefit from such development.

There is another side to this question, however—the economic one—which has been forced to the front by the developments in science, engineering, and industry during the past ten years, and this phase of the situation cannot be set aside without careful consideration. The development of power at Niagara to-day is not the result of vandalism. It is not a manifestation of the greed of the capitalists for further wealth, nor is it the evidence of the granting by legislatures of monopolistic privileges to the few. Broadly speaking, it is solely the physical expression of the law of supply and demand.

The prairies of the West have been turned to wheat-fields not to enrich the farmer, but because the wheat was needed in the growth of the country. The lumber lands of the continent have been cut and destroyed, not to enrich the lumber dealer, but to satisfy the irresistible demand for wood. So with Niagara Falls, the water is being diverted for power purposes solely because, in the economic and industrial development of the country, the power is needed. This demand, like all commercial demands, is the net result of the actions and desires of all the individuals of the country.

The economic value of Niagara Falls is probably understood by very few of those who protest and petition against its commercial use. The total hydraulic energy of the Falls, if all were developed, would represent about 3 500 000 horse-power. To generate one horse-power continuously for a year by a steam-engine requires about thirteen tons of coal. To generate, therefore, continuously 3 500 000 horse-power by steam would require about 50 000 000 tons of coal per year. To generate electric power by steam with the most modern steam plant costs not less than $50 per horse-power per year, allowing for fixed charges and operating expenses. Niagara power can be generated and sold in large quantities for $15 per horse-power per year, or for $35 per horse-power year less than is possible from the use of coal and the steam-engine. From the above it will be seen that if all the hydraulic energy of the Falls were utilized for power purposes, there would result to the country an annual saving of $35 per horse-power for 3 500 000 horse-power, or $122 500 000, and in addition there would be an annual saving in coal consumption of 50 000 000 tons. These figures illustrate what it costs the people of this continent annually to maintain Niagara Falls as a spectacle. They represent the saving to those who would consume the power, and not the profit of those who might own the power developments. This waste involved in prohibiting the development of Niagara power might be likened to a great conflagration in which 50 000 000 tons of coal were annually consumed. Such a conflagration might be one of the most magnificent sights in the world, and people might come from all parts to view it, but the human race would certainly be justified in using every effort to stop the waste by putting out the fire.

The men who have risked their money in the development of the power of the Falls have only obtained a reasonable return on their money and no more. They have not grown rich through their so-called monopolistic privileges, as is generally supposed. Those who derive the real benefit are the owners of manufactories and other industrial enterprises using Niagara power in their processes of manufacture, and through them those who purchase the manufactured products for prices which would not be possible without this cheap power used in their production.

The electro-chemical industry, which might be said to have originated through the development of Niagara power, has already reached enormous proportions, and its future growth depends largely upon cheap electric power. Already we have the carborundum industry and its widely extending applications; the calcium carbide industry and all the acetylene applications dependent upon it; the production of artificial graphite and emery to replace the loss caused by the depletion of the natural deposits; the caustic soda and potash industries; and, by far the most significant, the production of aluminum. All of these industries and many others are dependent for their existence upon the cheap power in large quantities available only at Niagara Falls. Many of the most brilliant minds in the world are at work upon the development of electro-chemical processes which pre-suppose for their operation the availability of Niagara power. Processes for the electric smelting of iron ores not reducible in the blast furnaces are at hand. If these processes cannot be worked by Niagara power, it will result in incalculable loss to the United States and Canada.

The aluminum industry, engaged in the production of this most important metal by an electrolytic process, requires large amounts of cheap electric power. The power item in the production of aluminum is so large a factor that the selling price of the metal must be proportioned on the cost of power used in making it. The applications of aluminum, and consequently the demand for the metal, are increasing with extraordinary rapidity, and unless this growth is to be stopped, cheap power must be available in large quantities. When one considers that the metal aluminum is one of the principal constituents of the earth's crust, the most common metal in our globe, and far more abundant in nature than iron, it becomes evident, as a logical deduction, that it is destined to rank in importance with iron and steel. This metal cannot be reduced from its ores without the use of electric power, and not commercially in large enough quantities without the use of Niagara power.

All of these fundamental industries and the various interests allied with them, together with their thousands of employees, are to have their ultimate destinies determined in the settlement of this Niagara power matter.

The utilization of all of the power of the Falls need not be considered at the present time. Whatever may be the ultimate conditions of power use, it is not now necessary to go further in the discussion than the rights granted to the various power companies now having charters. If all these charters were fully developed, about 1 200 000 horse-power would be available, or about thirty-five per cent. of the total energy of the Falls. It is not probable that such diversion of water would appreciably affect the appearance of the flow over the Falls. The eye judges a waterfall largely by two elements—height and width. The diversion of thirty-five per cent. of water from the crest of the Falls for power purposes would not influence the appearance of the Falls in either regard. By well known laws in hydraulics, the actual change taking place would be a diminution in the depth of water at the crest of the Falls and consequently in the thickness of the falling sheet. It is questionable whether such a change in thickness would be sufficiently noticeable materially to impair the grandeur of the general outlook at Niagara. The surroundings and settings of the scene would remain as before, and the general expanse of water would be the same. The Whirlpool Rapids, which many people consider the equal of the Falls in interest and beauty, would remain as they always have been, since the water used for power purposes would be returned to the river above them.

There has been considerable fear expressed that any further diversion of water for power use would dry up the American Falls. It may here be stated that in the course of time the American Falls will become dry, regardless of the development of power. Ten times more water now passes over the Horseshoe Falls than over the American Falls, and the consequent scouring of the Canadian channel now evident will drain off more and more water from the American side. The ultimate salvation of the American Falls will be found in the plan proposed by one of the power companies, and offered to be carried out as a condition of its development. The plan is to dredge a wide channel in the reef which projects out into the middle of the river above the American Falls. This reef has very little water on it, and consequently it acts as a wing-dam, deflecting the water above the rapids over to the Canadian side of Goat Island. It would be a simple problem in hydraulic engineering to dredge a channel in this reef, so that more water could be restored to the American Falls than could possibly flow there now even without any diversion for power.

The economic side of the Niagara problem is a serious one, and it cannot be set aside as secondary to that of the scenic interests. It must be cleared of the prejudices which now discredit it, and its importance to the country at large must be recognized. Niagara Falls is a great continental asset, not only as a scene, but also as a source of power, and any fair adjustment between the two interests must be made upon the basis of a reasonable compromise. The wave of exaggerated sentimentalism now passing should not be allowed to sweep aside all reason, nor be the only thing considered.

REGULATION IN VAPOR CONVERTERS

PERCY H. THOMAS
Chief Electrician, Cooper Hewitt Electric Company

THE question is often asked, "What is the regulation of a Cooper Hewitt mercury vapor converter?"

The term regulation in this connection means the drop in voltage produced in the delivered direct current by an increase in current from zero to full load, assuming the voltage of the alternating-current supply circuit to be constant. This term is usually used in connection with types of apparatus supplying energy to constant potential devices.

It is commonly assumed that the "drop" should always be as small as possible. Broadly speaking, however, a close regulation may or may not be desirable, according to the character of the apparatus using current. With apparatus requiring an accurately constant voltage, such as incandescent lamps, constant-speed motors, constant-potential arc lamps, etc., as small a drop as possible is desirable. With apparatus, however, which should be supplied with a definite current, such as a storage battery, a close regulation is rather a disadvantage, since any tendency for the current to vary will be greater with close than with poor regulation. Constant-current series arc lamps are an extreme example of apparatus requiring poor regulation in the supply; in fact, the drop must be artificially so magnified that on any value much exceeding a definite current, the supply voltage will be zero; and on any value much less than this current, will be nearly the maximum of the supply. In the constant-current regulator for series arc lamps, or the "tub" transformer, it is necessary to make an automatic alteration in the impedance in series, which causes the voltage drop with increase of current, in order that this drop may be sufficiently great.

When a circuit has a very poor regulation, or when the supply has a considerable ohmic or inductive resistance or its equivalent, it is commonly said to have a certain amount of "backing." Series arc lamps, for instance, have a very powerful backing, especially when operating with less than the maximum capacity of a circuit.

Returning now to the Cooper Hewitt converter, we cannot tell what its drop will be without knowing the character of load for which the outfit has been designed, for instance, whether for charging batteries or for running constant-speed motors. The actual drop consists of two parts,

(1) The drop of the bulb, and

(2) The drop in the auxiliary apparatus.

The drop in the bulb which is due to an increase of current, is nearly zero, being slightly negative, i. e., at a small current there is a certain voltage loss in the bulb, while at a higher current a little less voltage is lost. It is thus evident that the effect of the bulb is just the reverse of that of resistance, which causes an increased drop with increase of current, and will tend in some small degree to counter-balance ohmic drop in other parts of the apparatus.

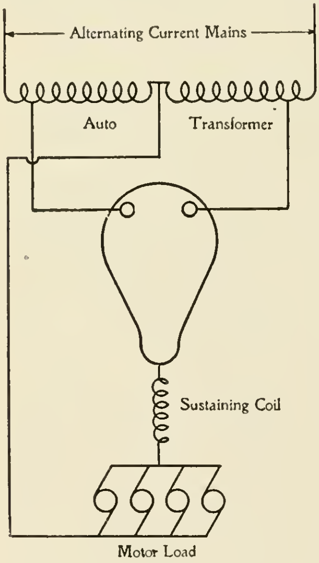


FIG. 1

The drop in the auxiliary apparatus is just what would be expected from its ohmic resistance and other characteristics in connection with any other electric circuit. For instance with the circuits shown in Fig. 1, which is intended for the operating motors, we have only the ohmic and inductive drop in the auto-transformer and in the sustaining coil. Since the sustaining coil is traversed by direct current, this is principally ohmic loss, which may be made insignificant in amount. On the other hand, with the circuits shown in Fig. 2, which is intended for battery charging, a poor regulation or a certain amount of "backing," as it is more often called, is obtained by the introduction of an impedance coil. This may be large or small as may be desired for the particular case in point.

As another example, we may use a Cooper Hewitt converter to change alternating current intended for constant alternating-current series arcs into direct current for direct-current arcs. In this case, the whole system is purposely made with an almost infinitely bad regulation, so that a constant current instead of a constant potential results.

The regulation of the vapor converter has this unique characteristic;

While in itself it does not cause a loss in voltage (but on the other hand, a slightly rising voltage) due to an increase in current, yet it enables auxiliary appliances to be used either in the alternating-current circuit or in the direct-current circuit for obtaining any desired characteristics of voltage regulation over a considerable range. It therefore permits the flexible qualities of alternating - current devices, such as impedence coils, "tub" transformers and the like, to be effectively utilized for the regulation of direct-current circuits. In this way the auxiliary apparatus used in connection with the converter may be designed to give a very small drop for constant potential, or an enormously large drop for other service, as may be desired. The design in each case is determined by the well known laws of alternating-current apparatus.

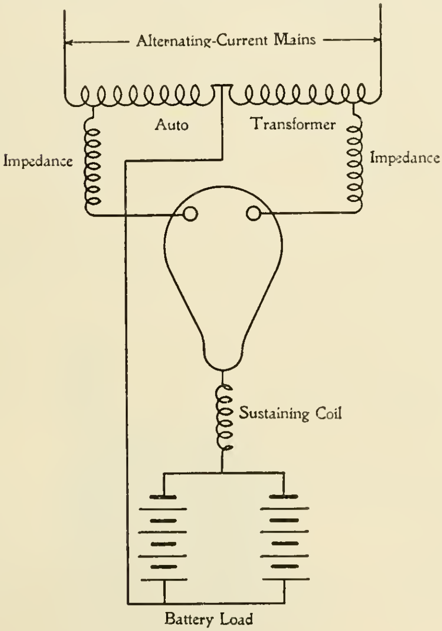


FIG. 2

THE APPLICATION OF THE AUXILIARY-POLE TYPE OF MOTOR

J. M. HIPPLE

THE auxiliary-pole type of direct-current motor described in the last number of the JOURNAL represents a distinct development in variable speed motor design and as such presents a very interesting problem to the designer. The results obtained in this type of motor in eliminating sparking and increasing the length of life of the commutator are of direct benefit to every user of electric motors. The action of the auxiliary poles and windings in producing sparkless commutation is a matter, however, which will be of less interest to the purchaser and user of motors than the question of how the development of a motor of this type makes a distinct saving in the lay-out and operation of the industrial power plant and its distributing system. The answer brings out certain facts.

Up to the time when the auxiliary-pole type of motor was commercially developed there was no single voltage variable speed motor with suitable speed characteristics which could be built in all sizes required for machine tool operation and for such speed variation as would give the best performance for each class of service.

As a result of this condition of affairs it was necessary in an industrial plant where there were motors having a speed variation of three to one or higher, to install a generating plant and distributing system capable of delivering a variable voltage at the motor terminals.

BALANCED THREE-WIRE SYSTEM

The three-wire balanced voltage system affords the simplest means of providing this variable voltage and there have been very many successful installations made where this system has been employed. Only two voltages are employed, usually 110 and 220 volts. The voltage between the outside wires of the system being 220 volts, and between the middle wire and either of the outside wires 110 volts. There is, however, a certain amount of complication and special work involved in installing this system which in many cases prohibits its use.

There are required in the power house either three-wire generators with stationary balancing coils, or two single voltage generators operating in series, or a single voltage generator with a balancing set.

The distributing system consists of three lines, the outside mains having capacity to carry the entire load and the third line or neutral wire having capacity to carry the unbalanced load, which with a properly distributed load is usually figured to be not over 25 per cent of the total. Under the worst possible condition of unbalancing the neutral wire might be called upon to carry 50 per cent of the total load. In ordinary practice, however, all three wires are of the same carrying capacity.

The controllers for motors operating on this system must be capable of handling two voltages and applying these voltages successively to the armature terminals. They are, therefore, of special design. The arrangement involves handling the full motor current on the controller contacts used in making the voltage changes, and thus necessitates a more cumbersome controller than in the case of a single voltage motor.

CONTROLLER FOR AUXILIARY-POLE VARIABLE SPEED MOTOR

UNBALANCED THREE-WIRE SYSTEM

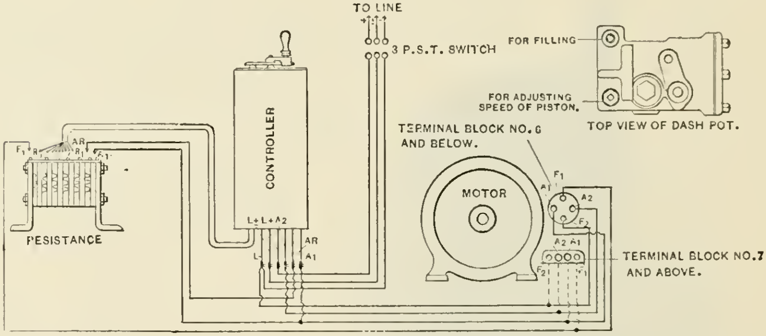
The three-wire unbalanced voltage system involves even more complication than the three-wire balanced voltage system, since it is not possible to distribute the load on the unbalanced system so as to insure a low current in the middle wire. Three voltages are employed, as before, 220 volts between the outside wires, then 80 volts between the middle wire and the outside, and 140 volts between the middle wire and the other side. This system is unbalanced, as the name implies, since with a motor load, the motors when running on their slow speeds, will all be connected to one side circuit, i. e., the 80 volt side.

The wires in this circuit may, therefore, be called upon to carry the current corresponding to the total motor load at 80 volts. This extreme condition is one unlikely to occur, but the varying demands on the line from a motor load are such that it may occur, and should therefore be provided for. It is also necessary to provide an additional amount of copper in all the leads so that it may be possible to operate the majority of the motors connected to the system on the lowest voltage.

The controllers are more complicated than those for the balanced voltage system since they must handle an additional voltage and higher currents.

FOUR-WIRE MULTI-VOLTAGE SYSTEM

The four-wire multi-voltage system employs one more distributing line than either of the three-wire systems and so delivers at the motor terminals a greater number of voltages and permits a wider range. The voltages in use commercially are 40, 80, 120, 200 and 240. This introduces further complication and a higher cost of installation since the balancing set for the system must consist of three machines, or two machines having three commutators; and the distributing system must be provided with sufficient copper to carry a large percentage of the total load connected to the system at the minimum voltage, or at any of the other voltages up to the maximum. This involves carrying from the power house four wires to each motor, or else locating balancer sets at various places on the distributing system and carrying the four wires from that point. The controller is also necessarily complicated as it must be capable of applying the various voltage steps successively to the armature terminals. As the minimum voltage is usually 40, 60 or 80 volts the currents to be handled are liable to be large, causing burning and short life on the controller and contacts.

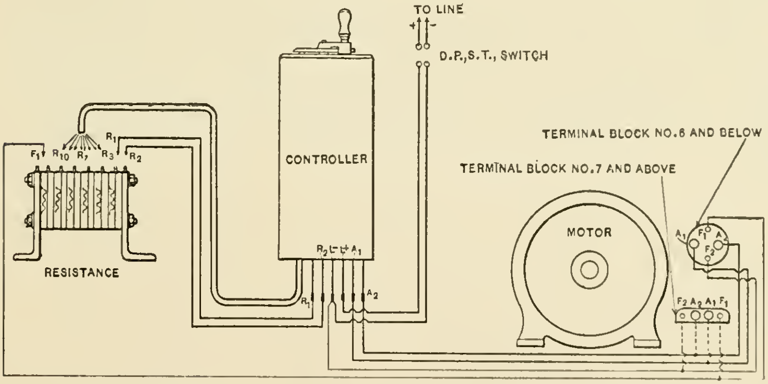


CONNECTIONS FOR CONTROL OF VARIABLE SPEED MOTOR ON TWO-WIRE SYSTEM.

With any of the variable voltage systems there is a certain amount of complication introduced. It may be said safely of the above systems that the amount of complication and the amount of additional copper in the distributing system will both be about proportional to the number of voltages used, assuming that the same maximum voltage is used in each case.

TWO-WIRE SYSTEM WITH VARIABLE SPEED MOTORS

With the advent of the auxiliary-pole type of motor in sizes and at speed variations suitable for all classes of machine tool work, it becomes possible and desirable in many industrial power plants to install standard single voltage generators and distribute power at 220 or 230 volts to all motors. It is then necessary to carry only two wires to each motor and as only one voltage is to be handled, all the power distribution will be at the maximum voltage, and, therefore, the amount of copper installed in the distribution system will be a minimum. This saving in copper becomes a very considerable item when it is born in mind that as compared with the four-wire multi-voltage system there will be just one-half as many lines.



CONNECTIONS FOR CONTROL OF VARIABLE SPEED MOTOR ON THREE-WIRE SYSTEM.

The control of the auxiliary-pole type motor is much simpler than the control of any motor requiring two or more voltages. The only currents to be handled in the controller in changing the motor from one speed to another are the field currents which are small and easily handled in the controller. The controller used may be made very compact and under ordinary service will give practically no trouble. It is not recommended in any case that the motor be controlled by separate starting and field rheostats. If there is no interlock between the starting rheostat and the field rheostat there is a possibility that the motor will be shut down when operating with the field resistance all cut in and, therefore, at the maximum motor speed. If the motor is again started with the field rheostat in this position the motor will be starting up under extremely weak field and will draw a heavy current from the line and will probably damage the motor. There is no possibility of such an occurrence with any controller which cuts out the field resistance when coming to the off position, or with an interlocking rheostat combining armature resistance and field resistance which accomplishes the same result.

It is believed that the saving in wiring and power house equipment made possible by the use of the single voltage power distribution will of itself be a large factor in leading to the general adoption of this system for industrial plants. At the same time the simplicity of the distribution system and the control makes the handling of the motors easy for inexperienced men and insures a minimum amount of trouble and interruption to work.

SELLING CURRENT TO CITIES OF TWENTY THOUSAND INHABITANTS*

H. C. AYERS
Manager and Superintendent of The Greenville Electric Light & Power Company, Greenville, Ohio

THE new central station starting operation has almost nothing to base rates upon, and when an investigation is made to find out what other similar stations are charging, they are confronted with the astonishing fact, that the prices range from two and a half cents to twenty-five cents per kw-hr. In flat rates, they find a variation almost as great. This is due to many causes; some stations charge almost all their expenses against their lighting peak and consider day power largely in the light of a by-product and sell it at a very low price; other stations are engaged in the business of furnishing heat from exhaust steam, and in order to have a large quantity of exhaust steam for sale, they make very low rates for power. However, the main cause for this great discrepancy lies in the fact that the stations are entirely ignorant of their cost of production and have adopted their rates without careful figuring.

The official of a new company making an investigation to find a proper rate to adopt, can find no rational reason for the large discrepancy that he discovers and concludes that the cost of producing electricity is as little known as electricity itself; he therefore adopts the rate which is deemed advisable and starts operation taking a gambler's chance on making profit. If there is gas competition, he probably has an engineer figure what rate he must charge to make a certain amount of electrical illumination cost the same as with gas, trusting to its superior advantages for getting his customers. There are two general methods of charging for current now in use among the smaller stations of this country, one being a flat rate of so much per light per month, the other being a straight meter rate of so much per kw-hr. Both of these systems have very serious objections and it is the purpose of this paper to describe a combination system using a fixed charge which is similar to the flat rate in combination with the meter charge.

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*From a paper read before the Ohio Electric Light Association, August, 1905.

The objections to the flat rate are pretty well known to most central station managers; the principal one is, of course, that your customers will waste current; it seems to be against human nature for a man to be careful if it costs nothing to be careless. The objections to a straight meter basis are, that it does not accurately distribute among your customers their proportionate share of the costs of supplying them and will always cause some customers to be operated at a loss to the company and others to pay in excess by an amount which makes up this deficiency, or in other words, the one customer is helping pay the other customer's light bill and this system discriminates against the long-hour user who is by all odds the more desirable customer, and the one the station wants.

The question of rates is by no means a simple one after several years of operation. The ratio between the maximum or peak load and the station's maximum capacity is constantly varying, the peak creeping up toward the capacity until it becomes necessary to install new machinery, when the capacity is again placed above the peak. These changes very materially affect the fixed cost.

I have assumed for the sake of illustration, a station of 300 kw capacity with a peak load of 225 kw and a total production of 500 000 kw-hrs per year. One year's costs of operating this station are assumed as follows, and are divided into fixed costs and varying or running costs as follows:

	Fixed.	Running.
Fuel and water		$4 000.00
Oil, waste, packing and chemicals		500.00
Officers' salaries	2 500.00	
Plant labor		2 500.00
Freight, drayage and expressage		100.00
Traveling and livery	200.00	
Office sundries	100.00	100.00
Plant and line repairs		1 000.00
Taxes	800.00	
Insurance	200.00	
Depreciation	5 000.00	
Interest	6 000.00	
Total	$14 800.00	$8 200.00
Grand total	23 000.00	

Dividing the grand total by 500 000 gives an average cost of 4.6 cents kw-hr at the switchboard and this result has very little bearing on selling rates as will presently be seen. It will be seen that the fixed costs are those that do not vary with the amount of current produced, but vary with the size of the plant or its capacity to produce a maximum amount, while the varying costs are those that vary with the production.

Dividing the total fixed costs by the maximum load of 225 kw gives $65.78 per year; dividing this amount by twelve gives a result of $5.48, which is the fixed cost per kw per month, and this amount should be received from each kw of load which comes on the peak to cover the fixed costs, the varying costs being covered by a meter rate as follows:

Assuming a loss in transmission of 50 per cent., we will have appearing upon the customer's meters 250 000 kw-hrs and dividing this into the total running cost gives 3.28 cents per kw-hr.

It will now be apparent, that each kw of the station peak should pay $5.48 per month plus 3.28 cents for each kw-hr shown by meter, plus a charge for lamp renewals if they are furnished, plus a profit, and any system of rates which brings an income of less than this amount in any customer's case, is incorrect and any system which charges in excess of this amount, is incorrect.

We will assume for illustration that the old rates of this station were 10 cents per kw-hr on a meter basis, or 50 cents per month for a 16 cp lamp on a flat rate, and that they now adopt a combination rate of 30 cents per month for each 16 cp lamp as a fixed charge, and in addition, all current shown by meter to be five cents per kw-hr.

We will now take a case of two consumers and see how the different rates correspond.

Consumer A uses 16.5 kw-hrs. per month by using one 16 cp lamp 10 hours daily for 30 days.

Consumer B uses 16.5 kw-hrs. per month by using ten 16 cp lamps one hour daily for 30 days.

	NEW RATE.		
Consumer A..........	F. C. $ .30	Meter 83c	Total, $1.13
Consumer B..........	F. C. 3.00	Meter 83c	Total, 3.83
	OLD FLAT RATE.		
Consumer A..........			.50
Consumer B..........			5.00
	OLD METER RATE.		
Consumer A..........			1.65
Consumer B..........			1.65

The result would be, consumer A would take his light on a flat rate and the consumer B his on meter and the station would lose on both, or if the station had only one rate, either the above flat rate or the above meter rate, they would have the losing customer in either case and the probabilities are, the other would use some other illuminant.

It is interesting to note in this case, that the flat rate brings the largest income and it is generally true, that customers will willingly pay more on a flat rate than on meter, the difference being that they will waste more than they pay for.

I would urgently recommend every station to discover its fixed and running cost and to this end would suggest a careful study of a paper read before this association last year by Mr. M. E. Turner, which treats the subject very fully.

After finding these costs a rate may be adopted consisting of a fixed charge and a charge for current as shown by meter, which will have the following advantages: It will accurately represent your costs plus a profit in the case of each individual customer; it will be a rate upon which you can make yearly contracts; it will be a rate which will be attractive to the long hour customer; it is also free from objectionable meter or discount complications, and last, but not least, your income and your customer's bills will not vary as greatly as on a straight meter basis.

In the application of this form of charging, there must be a classification of customers.

All customers who come regularly on the peak should pay the full fixed charge for the capacity connected to the station lines.

All six o'clock closing customers coming on the peak during the winter season should pay the full fixed charge.

Lodges and such clubs or meetings as are held but once a week should pay one-sixth of the full fixed charge, plus a certain small percentage to cover irregularities; this is for the reason that the same station capacity that was used by one on Monday night, would be used for another on Tuesday night, and so on.

Churches use on Sunday night the capacity used by stores during the week, but should pay some fixed charge to cover midweek meetings and extra meetings of various kinds.

Residences should pay the fixed charge on perhaps one-third of the capacity connected; this being fully up to their requirements at the time of the peak. At times there will be entertainments when a residence will use nearly all of its lights, but these times never occur in many residences on the same night, and are, therefore, taken care of by a very small station capacity, and as one-third is probably a high estimate of the portion of their total equipment turned on at the time of the peak, it would amply cover this extra requirement. I have also considered this one-third as being high enough above the average residence requirement to cover the extra cost of serving residences due to their scattered location and the necessity with alternating current of furnishing large transformer capacity.

The adoption of this rate might in some cases cause customers to wire only that part of their residences which would be used on the peak and in this case they should be charged the full fixed charge instead of one-third, it would be advisable to designate which rooms should be on the fixed charge and make a general rule to govern.

Each class of customers will have to be treated separately and considered as a detail of the business by the manager who should give the matter careful attention and see that the correct fixed charge is made, bearing in mind that the total fixed charge of all customers should represent the fixed cost as figured from expenditures.

EXPERIENCE ON THE ROAD

SOME TROUBLES WITH DIRECT-CURRENT INSTRUMENTS

ANDREW McTIGHE

THE average station attendant is generally considered capable of installing the ordinary types of direct-current meters; yet either through ignorance or carelessness, some amusing as well as serious results occur where meters are not properly connected or occasionally inspected aftey they have been put in service.

In one case the ammeter on a 25 kw exciter circuit had never given satisfaction. .To get a reading the case of this instrument had to be tapped until the pointer reached a place where further jarring would not change it. The scale on this meter was graduated in amperes, but in reality the instrument was a milli-voltmeter measuring the drop across a German silver shunt placed in series with the line whose current it was to measure. Two leads joined the meter to the shunt, and these leads should have been the ones used in calibrating the scale, as these instruments operate on about 45 milli-volts and a slight change in the resistance would change the reading. The writer was called upon to investigate the trouble. Instinctively he felt over the connections and merely tightening up one of the binding posts with his fingers to make good contact, corrected the fault. This is a common case. A dozen like it could be cited, where oxidization or dirt has covered the leads after being installed. Without proper care given to the connections the meters would not read accurately.

On another installation where two 37.5 kw direct-current generators driven by separate gas engines ran in parallel, there had been trouble in the operation of the plant. One machine ran perfectly while the other had always given trouble. Whenever full-load was reached and it was so divided that the meters indicated that each generator was taking its rated load of 300 amperes this second machine would flash and spark so much that within a year its commutator had to be turned off twice while the commutator on the other had not been touched. In looking after the work on a second trip the engineer was rather surprised to find such a condition. He discovered that the engine attached to the bad machine was barely able to carry full-load, while the other ran along finely under all conditions. It may be well to remember that gas engines are rated at their maximum capacity, so that generators driven by them are very rarely able to carry much above full-load. Investigation showed that the shunts for the meters, which were of the same type as those just described, had been interchanged, so that one instrument read about 18 per cent high, while the other read about 22 per cent low, and in actual operation the one machine had been carrying nearly 50 per cent more load for a year than its neighbor. The shunts were then changed to make the meters read correctly so that each generator would take its true share of the load, and the plant has ever since given the best of results.

Another case of this same trouble with this type of instrument happened where the total amperes on the two out-going feeders of the system failed to check with the currents indicated on the machine ammeters. Examination of the shunts revealed the fact that the ones on the feeders had been interchanged and when the correction was made the sum of the currents indicated on the feeder meters always equaled the machine amperes.

Quite a number of switchboard instruments are made in such a way that gravity plays quite an important part in their accurate reading, so that in mounting them on the board it is essential that they be set plumb. A rather disastrous result occurred a short time ago on a volt-meter of the type where an oil-immersed plunger is the core of a coil of wire and the reading is the result of the plunger pull which is dependent on the amount of current in the coil. The successful operation of a piece of direct-current apparatus was dependent on the voltage being maintained close to 500 volts. The distance from the generator in the power house was a mile, so that allowing a drop of 10 per cent, the voltage was held at 550. The service became so bad that the writer was sent to investigate the trouble and on reading the voltage with a portable meter at the operating end, it was found to be 585 volts. The voltage at the power house was 650 instead of 550 as indicated, the difference being entirely due to the careless mounting of the volt-meter, as the scale was correct when the meter was straightened up.

For this same type of volt-meter the resistance other than that in the coil actuating the moving element is wound on pasteboard cards and contained in a cast iron box to be mounted on the back of the switchboard directly behind the meter. A complaint was once made that the direct-current volt-meter on a small exciter circuit was reading 180 volts instead of 110, as was shown on a portable instrument. The engineer sent to the plant inquired where this extra resistance had been mounted. No one knew anything about it and by following out the circuit for the meter it was found that it had not been mounted at all.

The attendant stoutly maintained that if such an iron box went with this volt-meter it had never been received at the station, but a search of the engine room revealed the missing resistance buried in a trash barrel, from which it was extracted and put into service with satisfactory results.

A HOT-WIRE AMMETER

E. C. WHEELER

The equipment or a large power plant was recently installed in which the installation of the generators was in charge of one company and the installation of a bench type of switch board for the control of the plant was in charge of another company. The contract for the control apparatus stated that the use of the finished board or temporary apparatus was to be furnished for any tests that the purchasers might desire to make.

The company supplying the generators was ready to dry out their machines and notification was given to that effect. There were no ammeters on hand and none to be had at that time.

Some tests had been made by the writer a short time before to determine how much current was necessary to fuse copper wire and some notes had been kept of the amount of current necessary to heat copper wire of various sizes to a red heat. The idea occurred to utilize this data as a means of determining the amount of current in the generator when running on a short-circuit heat run. A few experiments during which a thermometer was kept in the windings of the armature showed this to be a thoroughly practical method, as the current was to be kept constant. The switch board operator simply had to look at the hot wire to note the current approximately. This arrangement was so satisfactory to the engineers present that they expressed the purpose of following the example if ever caught in a similar situation.

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Engineering Honor and Institute Branches

Aside from the presentation and discussion of technical papers, two topics which are of especial significance came before the recent convention of the American Institute of Electrical Engineers. In each of these there are ideas which are rival and are sometimes thought to be antagonistic.

The first of these was brought out by President Wheeler's address. It dealt with a function of the Institute which is often overlooked in the energy which is given to a second function, which may be termed engineering activity, under which the publication of papers, the educational influences of the Institute, and the dissemination of engineering and scientific information are foremost. Dr. Wheeler's theme was "Engineering Honor". He drew attention to the propriety and necessity of engineers regarding themselves as professional men, and discussed the relation of the professional engineer to the client, to the public, and to the engineering societies. The engineer is to protect the interests of his client, advise him what he ought to have and see that he gets it; he is to protect the public against misinformation and waste of money and energy in wild-cat schemes, and to advance the general estimate of the value of scientific and engineering work; he is to support the engineering societies, contributing to their professional, technical and financial welfare, because the society represents his art or craft, because it is to his advantage that it should attain a position of strength and recognition, and because he should stand well among the members of a society who are his peers and whose commendation the world will accept. He classes these as the moral duties of the engineer.

Engineering is so closely related to industrial and commercial activity that it is apt to be considered simply as one of the cog wheels of modern corporations, whose prime end is assumed to be the production of dollars. It is well that the professional side of engineering has been thus prominently brought to attention, and that a committee of the Institute will probably take up this general subject with the object of putting into crystallized form some of the professional standards which should prevail among electrical engineers.

Dr. Wheeler finds that the fundamental principle has been summarized by Francis Bacon in his preface to the "Maxims of the Law", where he says:

"I hold every man a debtor to his profession; from the which as men of course do seek to receive countenance and profit, so ought they of duty to endeavor themselves by way of amends to be a help and ornament thereunto."

The second topic, to which reference has been made, is the branch work of the Institute. Through the courtesy of the Cutler-Hammer Company a dinner was given on Tuesday evening to the officers of the Institute branches and of the Institute. At this dinner and the following day in the convention the representatives from various branches reported the work which had been done and asked that there be a closer relationship between the Institute management and the branches.

The governing body of the Institute, composed largely of members residing in New York, has held certain ideas with regard to the proper functions of the Institute, and in emphasizing the importance of the central and official body has underestimated that of the growing branches; while the scattered members, clustered in a score and more different places, without personal contact with the parent body, have found new interests and new possibilities in the local organizations of the Institute.

Never before have representatives of the two different ideas been brought together so effectively for an interchange of views and a mutual understanding of ideas and purposes as on this occasion. On the one hand, the officers found most emphatic reports of the good results which the branches may and are achieving and a most serious and earnest interest in the broadening and development of the Institute as a whole. If there lingered any idea that branches should be held back lest they rival and overshadow the parent organization, it was forgotten, as no such spirit was manifest. On the other hand, representatives from branches who felt that they had been too much neglected and had not received sufficient assistance and coöperation, found that the difficulty lay largely in determining methods and in developing a policy, and they appreciated some of the difficulties in the administration of twenty or thirty newly formed branches, differing widely in their surroundings and in the character and scope of their work.

Throughout all of the discussion it was significant that the question at issue was not whether the branch work was worth while, but it was, What practical methods can make it more effective? and, What means can best make the American Institute of Electrical Engineers a truly national organization, composed of many constituent branches, with a strong central administration?

Not only were general policies discussed, but definite plans were suggested, which may be carried out during the coming year.

Chas. F. Scott

The Present Status of Protective Devices

At the recent meetings of the American Institute of Electrical Engineers at Milwaukee and the National Electric Light Association at Atlantic City, more than usual attention was given to lightning troubles and devices for protection against static disturbances.

At the Milwaukee meeting the subject was treated in the form of papers on testing and operation of protective devices. A most interesting paper was presented by Mr. Farley Osgood, describing the troubles experienced at New Milford, Conn., entitled, "Experiences With Lightning and Static Strains on 33 000 Volt Transmission Systems".

The sum of his experience is that choke coils are beneficial and assist materially in reducing trouble from static disturbances. Also, that the series resistance element of multigap lightning arresters is a serious obstruction to the lightning discharges. The further observation was made, which, however, was well known before, that the omission of the series resistance permitted the arrester to hold the dynamic arc and weld the cylinders together, thus short-circuiting the system.

The paper by Mr. H. C. Wirt corroborated previous data on the advantages of the shunted multigap arrester and the efficacy of the non-arcing metal alloy.

The report of Prof. E. E. F. Creighton on the results of his laboratory experiments showed the interesting fact that the ability of the non-arcing metal cylinders to suppress the power current depended largely on the point in the e. m. f. wave where the break-down of the gap occurred. If the break-down occurs near the zero value no current will follow. If the spark passes some little time before the zero point, current will pass but will be suppressed when passing through the zero point. This holds for all points of the wave until the zero is approached again. The most severe condition is when the peak of the e. m. f. wave is still to follow after the spark has passed. This, of course, is the condition in which the largest amount of energy must be taken care of.

At the National Electric Light Association the subject was taken up in the form of a report on the results of lightning protection during 1905 from operating companies in various parts of the country.

The report shows that about one-half of the companies have suffered no damage whatever, and about one-third received serious damage to essential apparatus. With these, however, the greater amount of apparatus lost was of small size and of the older types having imperfect insulation and a scant factor of safety. While considerable data was received and tabulated, but little tangible use can be made of it because no argument can be deduced for or against any particular device. The only inference is to use more arresters and get new, well-insulated apparatus.

The following facts seem to be pretty well established by the information presented at the two conventions:

The non-arcing metal shunted multigap arrester is the best known device for suppressing the dynamic arc. Its power is limited, as too great a flow of current causes a "hold-over". A series resistance will prevent this, but a resistance is difficult to maintain and is inherently a detriment to the arrester. For this reason the ohmic value of the resistance should be kept as low as possible.

Choke coils are accepted as distinctly beneficial and desirable.

The final arrester must furnish a very free path for charges due to abnormal potential on the line, but must quickly suppress any dynamic arc so that circuit-breakers will not be tripped nor synchronous apparatus allowed to drop out of step.

With the present outlook the standard types of arresters supplemented by gaps and fuses for the most severe disturbances seem to offer the most promising avenue for progress.

R. P. Jackson

Co-ordinate Engineering

The very interesting article in this issue by Mr. Walter C. Kerr, president of Westinghouse, Church, Kerr & Company, descriptive of the scope and work of that organization, is highly instructive as showing how deeply the imprint of the engineer is made on almost every phase of modern life. There is, possibly, some danger that we engineers may fall into something of the frame of mind of the celebrated "tailors of Tooley street," who, it will be remembered, met and "resolved that we, the people of England," etc.; for this is certainly the day of the engineer; but I believe I was about right when I said in an address a few years ago, "If the physician does save life, it is the engineer who makes life worth living".

Mr. Kerr's article is an abstract of an address made to a gathering of Westinghouse men and unfortunately has to lose all of the personal allusions which he can make with rare felicity. As it stands, however, it will probably surprise most readers to find how wide is the scope of an organization which takes all of engineering for its field. It proves very conclusively how the man of scientific training is replacing the so-called "practical man". Above all, it emphasizes the importance of the commercial side of engineering, as to such an organization is committed everything connected with carrying out a project.

As the great enterprises of today cover many branches of engineering, the co-ordination of a number of engineers, experienced along different lines, is essential for carrying them through successfully. Hence, an engineering organization occupies a field which cannot be filled by the individual engineer. In such an organization the necessary co-ordination is absolutely assured, and the harmonious working of all branches is the regular every day work. The accumulated experience, systematically arranged and ready for instant consultation, enables the firm to pass upon the commercial feasibility of an enterprise very quickly. This, after all, is the matter of greatest importance. If an enterprise will not pay, it is poor engineering to undertake it, no matter how good the design or construction. Indeed, it would render absurd a favorite definition of the engineer as the man who can do for one dollar what any fool can do for two. Perhaps another definition, sometimes given, will soon come to be recognized as the best, namely, that the engineer is the man who can so expend the dollar as to bring the largest net return.

Firms of this kind are obviously well equipped for the development of engineering plans and the supervision of construction, as they have at hand the combined experience and ability of a large and varied force of men.

One of the striking paragraphs in Mr. Kerr's address is that in which he enumerates the different divisions of engineering work required in a single railway terminal. This is significant, both as it indicates specifically the wide range of matters which come under the general head of engineering and which call for expert knowledge, and also because it shows the comprehensive and intimate relation of the activities of the engineer in planning and executing the material facilities which are fundamental to our modern life.

W. M. McFarland

Electricity as a Fire Hazard

So much attention has been called to the fires caused by electricity, by the Fire Underwriters and others, that many persons have come to the conclusion that the use of electricity is extremely hazardous. A very interesting committee report on the Fire Hazard of Electricity was presented at the recent meeting of the National Electric Light Association.

Several tables from this report are reprinted elsewhere in the Journal. From the table giving the approximate total cost of the various illuminants per annum, it would appear that the use of electricity nearly equals the sum of all the other agents used for lighting.

In order to arrive at a fair conclusion as to the safety of electricity as compared with other mediums for the distribution of light, heat, and power, a territory (New York City) was chosen in which electricity is very largely used. Tables were prepared showing the total number of fires, as well as the magnitude of the losses from the various causes.

An analysis of these figures, which indicate the comparative danger of the most common everyday risks in the home, as well as in the public buildings, is very interesting. What is true in New York City should hold true in proportion throughout the country.

Only 361 fires were caused by electricity in this territory during the four years 1902-1905 inclusive. In this time, candles started almost four times, gas about six times, and lamps over twice as many fires as electricity; so that 11.4 times as many fires were caused by the other three illuminants as by electricity.

It was pointed out that practically every first-class building is lighted by electricity, and consequently fires caused by electricity generally started in valuable property. On the other hand, fires due to candles, lamps and gas are usually started in the poorer and therefore cheaper class of buildings. In spite of this fact, however, comparing the total losses due to these illuminants we find that electricity shows a considerably smaller loss than the combined lamps and candles, and only slightly more than gas.

When we figure percentages, the remarkable showing of electricity as a safe risk is even more clearly demonstrated. Only one and one-third per cent. of the fires were due to electricity, while fifteen per cent., or over one-sixth, of the total number of fires were due to lamps, candles and gas.

Tabulating the causes of fires in their order of magnitude, we find that electricity, instead of being near the top of the list, takes thirteenth place. Over eight times as many fires were caused by the handling of matches as by electricity, and any one of a number of risks which are very common in every house causes several times as many fires as electricity.

The total losses also show quite a small relative loss from electricity as compared with other common risks. The losses caused by stoves and furnaces, and by matches, are two and one-half times as much as those caused by electricity, while the defective flue is responsible for a greater loss than electricity.

This report also gives an interesting record, compiled by one of the large fire insurance companies, covering some 60 000 fires, which occurred in the various sections of the country during a period of seven years, from 1899 to 1905 inclusive. This record confirms the conclusions drawn from the tables mentioned above. The number of electrical fires is given as 2.8 per cent. of the total number, or less than one-fifth of the number due to lighting alone. The number of fires caused by matches is given as ten per cent., and heating (stoves, defective flues, etc.), twenty-one per cent.

Complete records such as these, giving the number and magnitude of the fires due to the various causes, are especially valuable, as they indicate the relative fire hazard involved.

The general public needs to be made well acquainted with the fact that the fire hazard of electricity is very much less than that of the other mediums which it displaces for the distribution of light, heat and power.

DEAN HARVEY.

ELECTRIC RAILWAY ENGINEERING*—V

EFFECTS OF CHANGES IN OPERATING CONDITIONS

F. E. WYNNE

ACCELERATION

A TRACTIVE effort of 100 pounds per ton is required to produce an acceleration of one mile per hour per second.† The tractive effort required for any other rate of acceleration is in direct proportion to this rate. At low rates, therefore, both the total tractive effort and the current for accelerating are less than for high rates and the time to attain any given speed is greater. Fig. 1 shows partial speed-time and current curves for accelerating a certain car with a four-motor equipment at rates of 1.0 and 1.5 miles per hour per second. From this it is seen that 135 amperes per motor are necessary for an acceleration of 1.5 miles per hour per

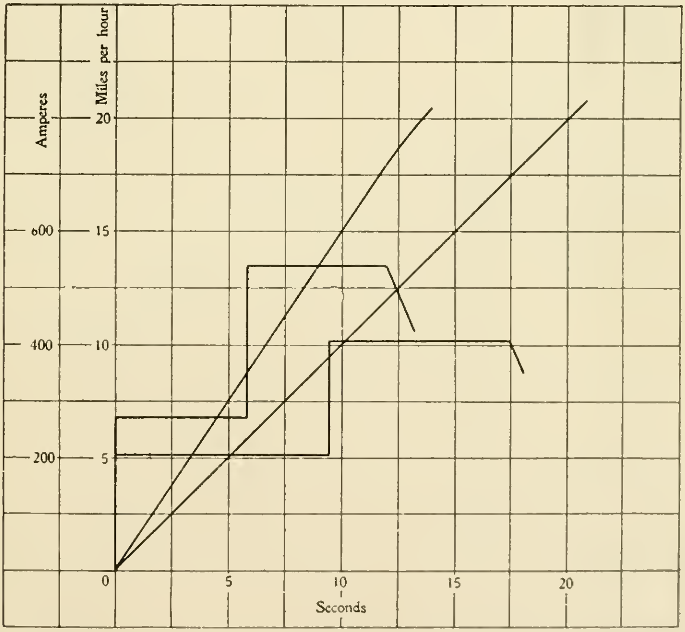

FIG. 1—SPEED-TIME AND CURRENT CURVES FOR TWO RATES OF ACCELERATION

second. With this acceleration, the speed at full multiple is 18.1 miles per hour and the time the car is running on resistance is 12.1 seconds. For the one mile per hour per second acceleration the car takes 101 amperes, the speed at full multiple is 20 miles per hour, and the time of running on resistance is 20 seconds. Fig. 2 shows curves between initial acceleration rate, accelerating current, speed at 500 volts, and time of running on resistance. On a run of unlimited length the car will reach the same running speed irrespective of the initial acceleration, but with

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* This is the fifth of a series of articles on Electric Railway Engineering. The first article appeared in the January issue.

† See *The Electric Journal*, Vol. III., No. 1, p. 12.

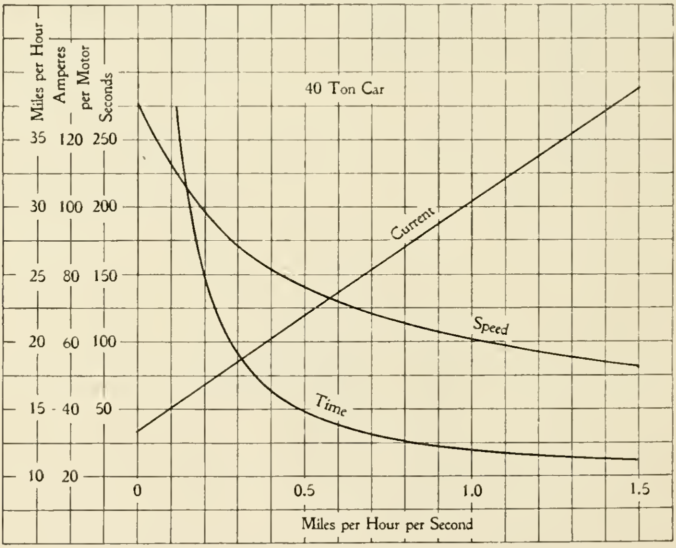

FIG. 2—CURVES SHOWING EFFECT OF RATE OF ACCELERATION ON INITIAL CURRENT, FULL VOLTAGE SPEED WITH INITIAL CURRENT AND TIME OF RUNNING ON RESISTANCE

a low acceleration more time will elapse and a greater distance will be traversed before this maximum speed is attained, than would be the case with a high initial acceleration. The lower the acceleration the less will be the distance traveled in any given time. Hence, to maintain a given schedule speed with a low acceleration necessitates having the power on the motors for a larger proportion of the total time and less coasting is possible than with greater acceleration; also the brakes have to be applied when running at higher speeds. The maximum possible schedule speed for a given run is greater as the rate of acceleration is higher. See Fig. 3.

A car running at a given speed has a certain amount of kinetic energy which was imparted to it during the period of acceleration and which is proportional to the square of the speed. The greater part of the energy expended by the motors while accelerating a car is thus stored up as kinetic energy and is available for useful work in propelling the car after power is cut off. This stored energy is what keeps the car in motion when coasting. When the brakes are applied the remaining energy (except that used in overcoming the train resistance) is consumed in heating the brake shoes and wheels. Therefore, the total energy drawn from the line is the sum of the energy needed to overcome the train resistance throughout the distance traveled, the energy consumed in braking, the energy lost in the rheostats when starting, and the losses in the motors and in the car wiring.

For any given run, the energy expended in overcoming train resistance is constant. The amount lost in the rheostats depends on the rate of acceleration and is greater with low accelerations. That consumed in braking is dependent on the rate of braking and the car speed when the brakes are applied.

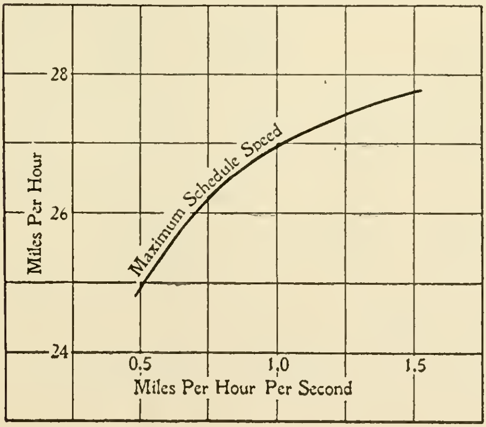

FIG 3—CURVE SHOWING EFFECT OF RATE OF ACCELERATION ON MAXIMUM SCHEDULE SPEED

The losses in the wiring are usually small and may be neglected. The motor losses are approximately a constant percentage of the input to the motor throughout its usual working range. Assuming a constant braking rate, the greater the car speed when the brakes are applied the greater will be the power consumed by the brakes. In general, then, a run made so that the brakes are applied from a high car speed will take more power from the line than if made so that braking begins at a low car speed. Fig. 4 shows curves between acceleration, average current consumption and rheostatic loss for a certain car.

The copper loss in the motors is dependent upon the square of the current, hence an increase in accelerating current tends to produce an increase in the heating. With increased acceleration, however, the time during which power is on, is decreased, thus tending to reduce the heating. The result of these opposing tendencies which occur simultaneously is that first one and then the other predominates and for a given run there is one rate of acceleration which will give minimum heating. Fig. 5 shows this graphically, the curve being drawn between acceleration and square root of mean square current values. For this particular case, it is seen that an acceleration of 1.55 miles per hour per second is the best, so far as the heating of the motors is concerned.

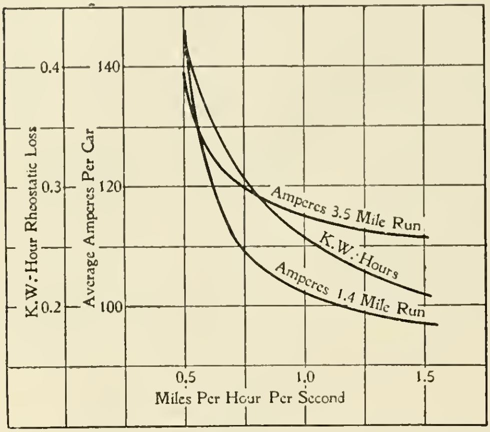

FIG. 4—CURVES SHOWING EFFECT OF RATE OF ACCELERATION ON AVERAGE CURRENT CONSUMPTION AND RHEOSTATIC LOSSES FOR TWO RUNS OF DIFFERENT LENGTHS

A method of reducing the maximum power taken from the line by a car when starting has been devised by Mr. N. W. Storer and may be used where the grades are light and the equipments are arranged for automatic acceleration. By means of two limit switches, one in the motor circuit and one in the line circuit, constant current per car is used for accelerating. A high rate of acceleration is used in coming up to the series running position, the current per motor being kept approximately constant. The motors continue running in this position until the current per motor has decreased in value to one-half of that used while accelerating in series. At this point the parallel connection is made and the accel-

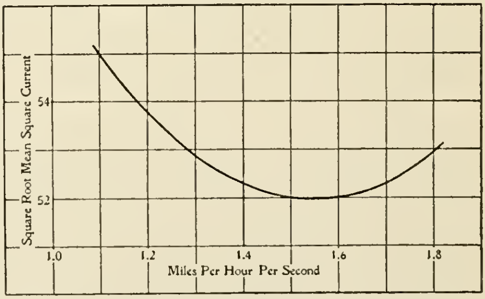

FIG. 5—CURVE SHOWING EFFECT OF RATE OF ACCELERATION ON SQUARE ROOT OF MEAN SQUARE CURRENT

eration continues in the usual way, the current per motor being held at this value until all the resistance is out of the circuit. The rate of acceleration in the parallel position is somewhat less than one-half of that obtained with the motors in series. The compensation for this slight disadvantage is found in the higher permissible acceleration while running in series and in the decreased value of the maximum current taken from the line in starting. Fig. 6 gives a comparison of the speed-time and power curves for a car operating on a certain run when using this method of acceleration and when accelerating in the usual manner. This particular run shows practically the same power consumption and heating of the motors for the two methods. However, with constant current per car, the peak of the power curve is only 75 per cent. of the peak with constant motor current.

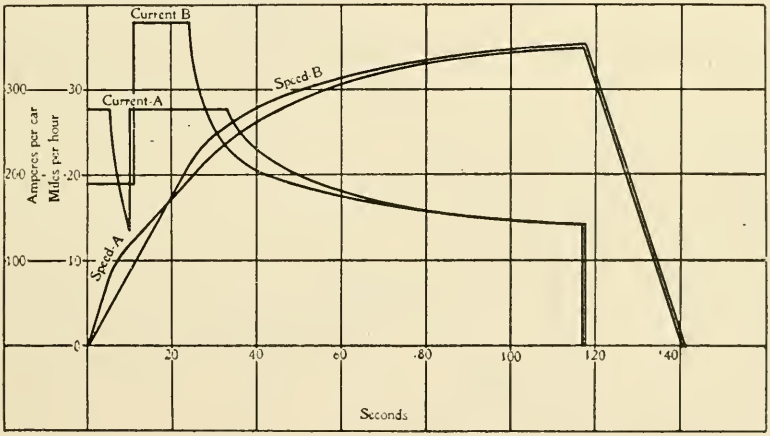

FIG. 6—COMPARISON OF SPEED-TIME AND POWER CURVES FOR ACCELERATION WITH CONSTANT CURRENT PER MOTOR AND WITH CONSTANT CURRENT PER CAR

LENGTH OF RUN

Assuming that other conditions remain the same, the maximum possible schedule speed increases with increased length of run. The general relation between possible schedule speed and length of run is shown in Fig. 7.

The proportion of the total energy drawn from the line used in overcoming the car losses and in braking is less for long runs than for short ones.

Therefore, in general, the power consumption per car-mile or per ton-mile is decreased by increasing the distance between stops. See Fig. 7.

Large starting current affects the heating of the motors to a much greater extent in short runs than in long runs. Fig. 7 shows this relation also, the heating being measured approximately by the square root of the mean square current per motor. From this it is seen that in general the heating is less as the run is longer. Since the heating determines to a large extent the size of the motors to be used for a car, it follows that to operate a car of given weight at a given schedule requires larger motors as the stops are more frequent. Fig. 8 shows the curves of Fig. 7 plotted with the number of stops per mile as a base.

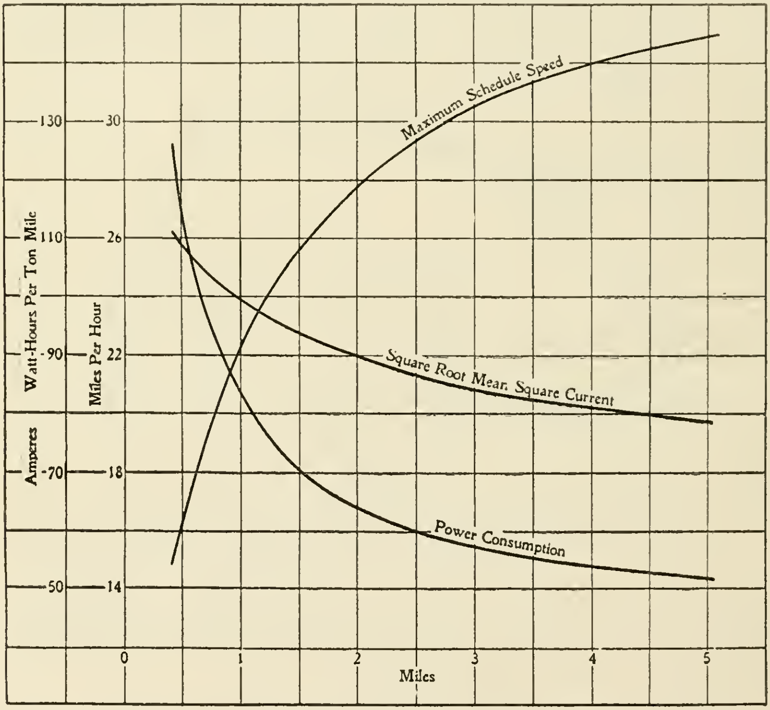

FIG. 7—CURVES SHOWING EFFECT OF LENGTH OF RUN ON MAXIMUM SCHEDULE SPEED, SQUARE ROOT OF MEAN SQUARE CURRENT AND POWER CONSUMPTION.

As the distance between stops is increased, the less will be the effect of change in any of the conditions which are present during only a part of the run, because as the run is lengthened the car is running at constant speed a greater proportion of the total time. Hence a change in the rate of acceleration, rate of braking or length of stop within reasonable limits has less effect upon the performance of an equipment with long runs than when stops are frequent. This may readily be seen in so far as changing the rate of acceleration goes by referring to Fig. 4. The variation in current consumption for the 1.4 mile run between accelerations of 0.5 and 1.5 miles per hour per second is 51 amperes, while for the 3.5 mile run the same change in acceleration makes a difference of only 28 amperes.

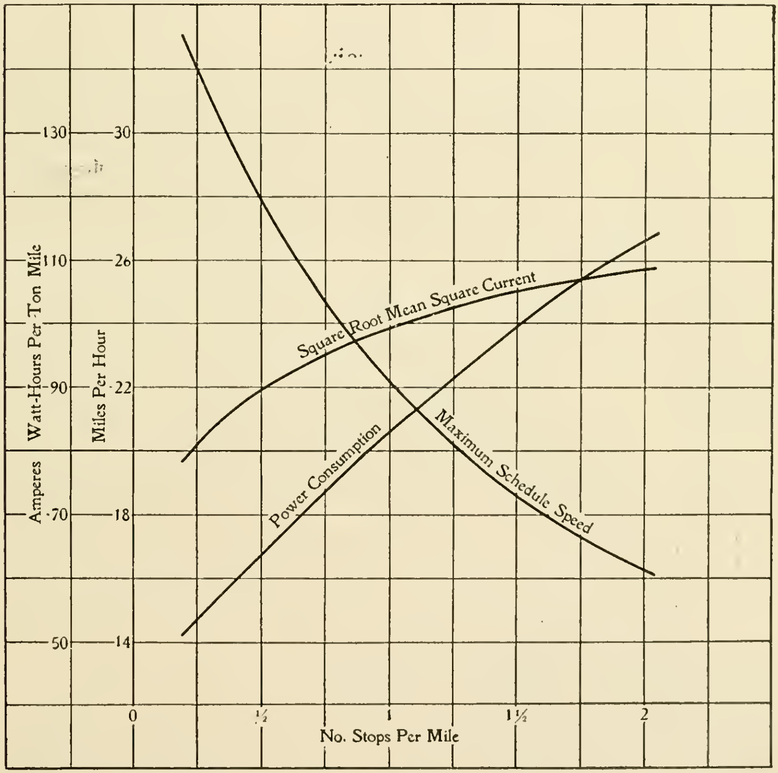

FIG 8—CURVES SHOWING EFFECT OF NUMBER OF STOPS PER MILE ON MAXIMUM SCHEDULE SPEED, SQUARE ROOT OF MEAN SQUARE CURRENT AND POWER CONSUMPTION

LENGTH OF STOP

The length of time during which a car is at a standstill for the purpose of taking on or discharging passengers or freight has a decided effect upon the possible schedule speed. With long stops it is, of course, impossible to maintain so high a schedule speed as when the stops are short. When operating at a constant schedule speed the power has to be kept on the motors a greater part of the time as the stops are longer, with the result that the power consumption and heating are greater. An example of this is shown in Fig. 9. As the distance between stops is increased, the effect of length of stop is lessened.

BRAKING RATES

The effects of the rate at which the brakes are applied to stop a car are very similar to those produced by change in acceleration. In long runs, the braking rate is of little moment, but in short runs it becomes an important factor. A high braking rate is advantageous because it allows more coasting in any run which means an earlier point of cut off, resulting in lower power consumption and less heating of the motors than would accompany a low rate of braking. Fast braking also tends to minimize the size of motor for a given service.

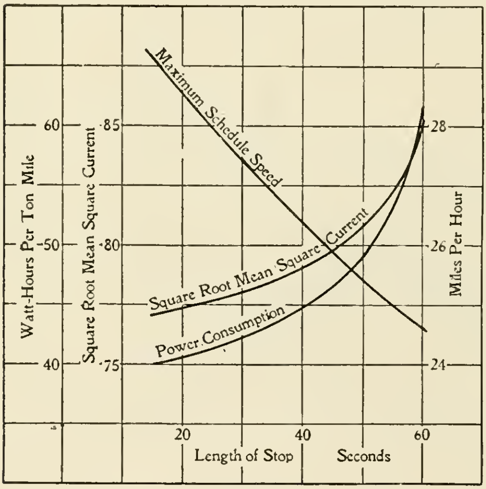

FIG. 9—CURVES SHOWING EFFECT OF LENGTH OF STOP ON MAXIMUM SCHEDULE SPEED, SQUARE ROOT OF MEAN SQUARE CURRENT AND POWER CONSUMPTION

LINE VOLTAGE

The speed of a series motor with a given load varies almost in direct proportion to the applied voltage. Hence the maximum speed which a car will attain is dependent upon the line voltage. The line pressure also determines the best possible speed in a given service with a given equipment. In making a given schedule speed with a fixed initial acceleration, the running speed at any instant after the rheostats are cut out will be lower with reduced voltage, as is shown by the more sudden braking over of the speed-time curves at 400 volts in Fig. 10. Therefore, in order to maintain the schedule with reduced voltage, it is necessary to keep the power on for a longer time. This generally produces greater heating and requires more power than with normal voltage. An exception to this general relation is found in very short runs, such as are made by interurban cars passing through cities. Fig. 11 shows the speed-time and current curves for a one-quarter mile run made with the motors in series and also as made when using the series-parallel connection. The respective rates of acceleration are taken as 1.5 and 0.85 miles per hour per second in order that the braking line may be the same in both cases. Although the current per motor for the initial acceleration is greater for the series run, this is more than compensated for by the shorter length of time the heavy current is maintained. The result is that the heating of the motors is the same in the two cases but the series run shows a saving of 18.25 per cent. in the power consumption. The conclusion from this is that when high speed interurban cars are operating in cities where both the maximum and schedule speeds are low, power will be saved by running in the series position as much as possible. This method has a further advantage in keeping down the maximum power required from the line.

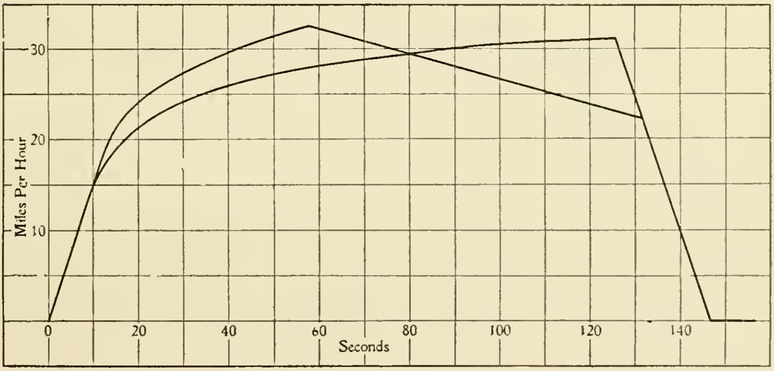

FIG. 10—CURVES SHOWING EFFECT OF LOW VOLTAGE ON SPEED-TIME CURVES

The higher curve is speed-time curve at 500 volts (normal). The low curve is speed-time curve at 400 volts (voltage 20 per cent low).

Good line pressure is important on grades. Heavy grades work motors at an overload, the degree of overload depending upon the amount of grade. A railway motor will safely carry any overload within its commutating capacity for a certain length of time. The length of time that any overload will last depends upon the voltage at the motors. For instance, a certain grade will require 175 amperes per motor at a speed of 16.5 miles per hour at 500 volts. If this grade is 1.5 miles long the overload will last 5.5 minutes, which is within the capacity of the motor. If, however, the average pressure on the grade is only 400 volts, the speed will be only 13 miles per hour and the overload will last seven minutes, at the end of which time the temperature of the motors will be above the limit of safety. With a constant line voltage, Fig. 12 shows the effect of grades on the speed-time curve for a given run.

GEAR RATIO

The gearing of the motors on a car determines the car speed and the tractive effort with a given current and constant voltage.

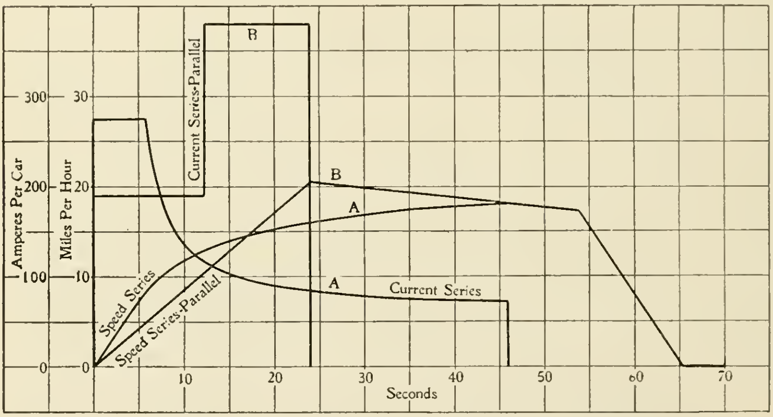

FIG II—COMPANION OF SPEED-TIME AND CURRENT CURVEES FOR TWO RUNS, ONE WITH MOTORS OPERATING IN SERIES-PARALLEL, AND THE OTHER WITH MOTORS IN SERIES ONLY

Since the horse-power of a motor is constant for a given current and is directly proportional to the product of the car speed and tractive effort, it follows that with a high car speed the tractive effort is correspondingly low. A motor geared for high car speed takes greater current to produce a given tractive effort than is required with a low-speed gear; also the speed corresponding to a given tractive effort is higher. Hence, with higher speed-gearing the current to give a certain rate of acceleration, is greater and the power required on grades and curves is increased. On the other hand, the time consumed in traversing grades and curves is decreased and it is possible to make any fixed run at a given schedule speed with more coasting and less braking than with motors geared for low speed.

With low-speed gears, it may be impossible to make the desired schedule or the amount of coasting may be so small that the power consumption will be unduly large. In descending grades with low-speed gearing there is also the danger of getting an unsafe armature speed before the car speed is at all excessive.

Probably the most common error in gearing is to gear for high speed where the service is such that the stops are frequent and there is no opportunity to run at high speed. The typical cycle for such runs is rapid acceleration, short coast and rapid braking. Consequently the acceleration and the run, to be accomplished most efficiently, would be made with a low-speed gear. That which is so self-evident in this case holds good in lesser degree with longer runs. Therefore, having selected a motor with sufficient capacity for a given service, the best gear ratio to use is the lowest speed gear which will give the required schedule speed with a reasonable margin for making up lost time.

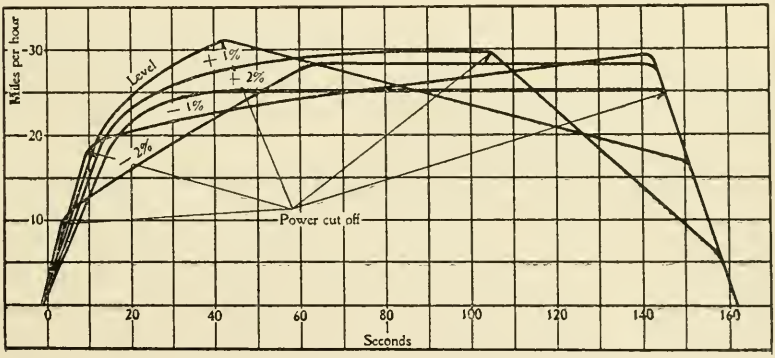

FIG. 12—CURVES SHOWING EFFECT OF GRADES ON SPEED-TIME CURVES

One mile run, 40-ton car, initial current 134 amperes per motor:

Grade per cent	—2	—1	0	+1	+2
Watt-hrs. per ton mile	5	14.2	42.5	85	125
Square root mean square current	21	33	44.5	56.5	72.8

SOME COMMENTS UPON THE NEW HAVEN ELECTRIFICATION*

EVERY progressive electric railway man cannot but feel an absorbing interest in the electrification of the New York, New Haven and Hartford main line between Stamford, Ct., and Woodlawn, N. Y., for the reason that the installation will mark the first notable application of alternating-current locomotives to trunk line railroad service in this country.

The estimated cost of the electrification from Woodlawn to Stamford is about $2 750 000. This includes 21.45 miles of overhead construction costing $570 000; a 12 000 kw power house near Stamford, at $1,130,000, and 35 alternating-current electric locomotives costing $1 005 000.

Between the bus bars at the power house and the locomotives there will be but a single link in the transmission of energy—an 11 000-volt trolley wire. At a recent meeting of the New York Railway Club, Mr. Calvert Townley stated that if the ordinary system of high tension transmission with rotary converter sub-stations had been adopted, there would have been no less than eight links between the power house and the rolling stock:

A transmission line,
Sub-station switchboard,
Step-down transformers,
Rotary converter,
Direct-current switchboard,
Storage battery,
System of direct-current feeders and
A 600-volt third rail.

The supporting of the trolley lines by bridges spaced 300 feet apart, with extra substantial or anchor bridges every two miles, strikes one as a thoroughly common sense proposition, for it affords the opportunity to combine the suspension of the block signals and other auxiliary apparatus with the trolley suspension. The highest standards of mechanical and electrical construction must be adhered to in such heavy work, and the permanence of the steel bridge with concrete foundations renders it particularly applicable to this problem. It is interesting to consider the comparatively long span which the bridge and catenary plan allows, in comparison with the spans found in ordinary trolley work, four or five to one in the former's favor.

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* Condensed from an article in The Street Railway Bulletin.

The key to the whole problem of long distance steam railroad electrification is found in high voltage upon the working conductors, in the light of present knowledge. At the New York meeting Mr. Lamme pointed out that a single power house will be able to supply about 40 miles of railroad line with power without the use of any kind of sub-station, if the power house is located near the middle of the line.

It has been pointed out that in the event of a derailment the striking of a train against one of the steel bridges supporting the 11 000-volt line might cause great damage to life and property. Humanly speaking, it is impossible to divorce all risk from modern railroading, and there is little doubt that the use of even a protected 600-volt third rail might give a great deal of trouble in the event of a severe derailment. It does not seem as though the prospect of breaking the bridge columns by derailments should warrant the exclusion of the 11 000-volt system any more than that all trains should be run around curves at 20 miles per hour lest the breakage of a wheel or axle at a higher speed throw the entire outfit into the ditch. The use of double steel cables and triangular catenary suspension of trolley wires would seem to be an added insurance against trouble from high voltages. A factor of safety of six in the cables with a load of ice one inch in total thickness on wires and hangers is certainly liberal.

The details of the New Haven electric locomotives are full of interest and in many respects appear to be admirably worked out.

The fact that steam locomotive engineers are to operate the electric machines has never been lost from sight, and in its characteristics of variable speed over any required range, and consumption of power in proportion to the load, the new single-phase locomotive is essentially in the same class as its steam-driven prototype. The voltage control in the motor is the equivalent of the combined throttling and variable cut-off in the steam locomotive. Six operating voltages or running points in the alternating-current control insure a good speed range, and this with economy of power with rheostat direct-current control.

While the motors are of the same general type which the Westinghouse Company has been building for interurban service of late, there are a number of interesting features deserving of special comment. The method of supporting the armature upon a quill, with a flange and pin-wheel drive is of novel construction. No gearing is employed, and the commutator speed is only 3 000 feet per minute at 60 miles per hour. A specially good point is the use of air in cooling the motors, which gives a continuous capacity of 200 hp each, against 250 hp nominal capacity. The flow of air is outward, which tends to keep the motor interiors clean. When running on direct current several efficient controller running points between series and multiple are made available by shunting the motor field, an expedient which adds considerably to the flexibility of the machine. The balancing of the transformers in the cab by installing one for each pair of motors, with their high tension sides in multiple is another feature which evidences careful design. In fact, the entire mechanical design deserves the most disinterested praise. The provision for taking care of end play and for preventing abnormal bumping strains are exceedingly interesting, and it is to be hoped that they will stand up well in the actual service operation of the locomotives.

In closing, the writer ventures to quote from Mr. Townley's remarks at the New York meeting referred to above, for they contain the nub of the entire heavy electric railroad multiple unit question:

"In handling heavy freight traffic, or even high-grade passenger traffic, instead of having to keep down the length and weight of trains in order to obtain the necessary speed; instead of being limited to a maximum locomotive weight by the strength of bridges and other structures; instead of being hampered by the consideration of maximum sized wheel base and the maximum weight per driving axle; by using two or more locomotives connected together by the multiple-unit system, it becomes feasible to get practically any amount of speed and any amount of tractive power that is needed to perform a given service. It follows that the size of train units, whether passenger or freight, can be increased up to any extent desired, and be limited only by the strength of the draft gear of the rolling stock."

WESTINGHOUSE, CHURCH, KERR & COMPANY

WALTER C. KERR, PRESIDENT

TO properly understand Westinghouse, Church, Kerr & Company's operations and motives, it is well to look back a little to see how it came into existence and to learn some of its history, because this concern has been somewhat misunderstood, for the reason that it has been a number of different things in its time.

The company was organized in 1884, twenty-two years ago, primarily to sell the product of The Westinghouse Machine Co. The W. M. Co. at that time were selling their own product through agents and were in the process of making an arrangement by which they would wholesale their product to certain concerns who would act as dealers rather than agents. H. H. Westinghouse, Wm. Lee Church, Isaac H. Davis, and myself put our heads together and organized W. C. K. & Co. to take over the sales business of The W. M. Co., buying of the Machine Co. and re-selling on our own account in the territory east of and including Pittsburg.

We then actively built up an engine business, doing also some other things. About a year later, Mr. George Westinghouse, who was then making some electrical apparatus on his own account, wanted us to sell it for him, and so we added an electrical business. Shortly after this, the Westinghouse Electric Co.—not the W. E. & M. Co., but a prior organization—was formed, and we handled its entire product for about two years—mostly installing small, isolated plants and building two or three central stations.

This continued until February, 1887, by which time the W. E. Co. had prepared to undertake larger things and proceeded to develop their own departments and properly develop their own sales activities. They then bought from us whatever stock we had on hand, with fair compensation for good will, existing orders, etc., took over the electric sales, while W. C. K. & Co.

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* This artice is a revision, by the author, of a paper read before a private gathering of business associates. It traces by concrete example the development of the methods of conducting commercial engineering work during the past twenty years, and shows the broad scope of engineering activity in a modern engineering asociation.—Ed.

again turned their whole energies to the engine business. So there was a period of two years in which we were also the sales outlet for the Electric Company.

The next development was the adding of small contracting to engine selling. We also did something which was then rather novel, practically the forerunner of what is regular practice now, and that was the introduction of real engineering into sales effort. Prior to 1885, such salesmanship did not involve anything like the amount of engineering effort which has since accompanied it, and we were among the earliest to introduce that effort. That quickly led into large contracting, and we were soon taking on engagements of various kinds, mostly pertaining to power plants. Meanwhile we added the Roney stoker and developed it, and also boiler furnace work extensively.

The contracting business grew until in the course of time it became the larger part of our business. We bid on jobs to win or lose, and we made money handling such work.

We always put a good deal of engineering into the contracting effort, and that led in time to the doing of engineering for clients, and so by a strange anomaly we were at one time contractors, engine sellers and engineers. These occupations represented an anomalous combination, but the world was pretty anomalous and it could stand a little more without over-running the elastic limit.

In the course of time we retired from contracting in the ordinary sense of bidding for and doing lump sum work. We then had left the anomaly of being engineers while also selling the product of The W. M. Co.

Soon the Machine Company developed into a large concern, building engines large and small of many types instead of a small, specialized product. Thus it became expedient for them to establish their own selling department. We then turned over the engine selling business, relinquishing about sixty-five of our men to them, in addition to the field force on this work. That marked the time when we really became the concern that we were destined all of the time to be—a purely engineering organization with nothing to sell, our work being rendered entirely in the interest of the client and not with a trade motive. Thus it took nineteen years for us to work out our destiny. It is not strange that some think we are engine sellers, others consider us contractors, while many know we are engineers. This is perfectly logical, for not very long ago we were all these things.

We have always tried to make this engineering organization the proper interpretation of what the country needs just at any particular time because if we do just what the most important people want done we are pretty sure to constantly find acceptable work. We don't want to be too far ahead of the time, and never behind it.

The period of 1897 to 1899 was a turning point in our history. We had been doing engineering, selling and contracting more or less mixed together. There began to appear a larger and higher class of work than we had experienced. There were distinct signs in the air. Chief among them was the Boston Terminal, of which you have all heard many times. That was a mile-stone in our history. The late Mr. Charles P. Clark, then president of the N. Y., N. H. & H. R. R., wanted certain things done. He particularly wanted some one to do the things, not to tell him what to do. It turned out that we had the capacity to do these many things. His insistence in the matter caused us to rise to about the maximum ability which we were able to display, with the result that we undertook a varied piece of engineering work, consisting of about sixteen kinds of engineering, putting them all through co-operatively and co-ordinately, which at the time it was done was considered a great engineering undertaking, although the total cost of what we did was only about $600 000.

Then came a rapid development. We found ourselves. We began to understand the strength we had been gradually developing in engineering. We got the size of our men and accelerated the pace of a development which was partly our own and partly due to the demands of the world. We found a large number of people who wanted some one to come and do for them what they had to do. They were not looking for some one to advise them what to do, but they wanted some one who could first design and then do all of the things they wanted done. As soon as we seized upon that theme and were willing to do anything any one wanted, a more versatile organization began to grow. Large work caused us to increase our force, an increased force made us more capable of doing larger work, which made us more capable of increasing our force, and so we have increased to our present proportions, employing about 450 in our offices and from 1 000 to 7 000 workmen in the field.

It was growth, not direct creation. After many years' experience in handling engineering work, I have reached the conclusion that it is impossible to quickly make an engineering organization. It must grow. Consequently it takes time, because growth takes time. An engineering organization, regardless of how good the units may be of which it is composed, is unreliable until the units have worked together a long time. Until the men that do not work together are weeded out, you cannot get an effective organization for comprehensive work, so part of the virtue and competency of any engineering organization is its very age.

There is one way to get a rather clear idea of what W., C., K. & Co.'s engineering organization does. Divorce from your mind that anything they do may be called by a name, such as an industrial works, a power plant, or a railway terminal, and concentrate your perception on the fact that they are organized to take care of a client's necessities. It is then immaterial whether such necessities involve the electrification of a railroad or building a hotel complete; the design and construction of structural steel or building a female seminary; the production of a power house or designing a large concrete cow barn; the equipment of a railway terminal property or turning out a set of railway shops or other complete industrial plant; the running of preliminary surveys for rights of way or the making of engineering and statistical reports upon projects. Everything is grist that comes to our mill.

The very essence of a competent engineering organization is that it shall be able to do all of the things that need be done. This seems complicated, but it is much less complicated and easier than to be constantly confronted with something it can't do.

The motive of our concern, from its officers down through its men, is this: We absolve ourselves from the hope of any extraordinary or speculative gain, and accept an assured fixed percentage, which satisfies us, and we then discharge entirely any question of personal or corporate gain. Thus every effort from the head to the foot of the concern is bent upon serving every possible economy of the client.

In the working of these economies, I want to point out what makes for economy. The first is design, the second is field management, and the third is purchase. A great many people invert that order. Proper purchasing and field construction, of course, have opportunities for great economies, but the greatest economy comes in design, in the conception of and the way of going at things. We often cut $100 000 out of cost by a change in the design, with a better result. I can show you something constructed by us within the past year at a cost of about $130 000 and another plant of a little more than half its ultimate capacity for the same purpose constructed by others at a cost of about $450 000. The difference was not caused by administration of purchase or field work, but by sufficient attention given to original design. Such results can be obtained only when engineers have for their motive the interest of the client, when the whole undertaking is designed and constructed and carried through as a unit in the engineering spirit. That is the plan on which we are working.

We have some limitations. The chief one is human nature. We are also brought into contact with the limitations of those with whom we deal—those whom we can't control. Our client's limitations almost become our own. We have to act more or less on their limitations.

Another limitation is that if our skill saves a man $100 000 it is not valued nearly as much as he values an engine or generator for which he pays $20 000. Advice, design, or method that saves money is not valued as material things are valued. If you look over the history of engineering for twenty-five years, you will see that very few engineering concerns have been successful. The ones who have succeeded are mostly those who have had some other motive than engineering, the financial motive, dealing in securities, etc. We have always had limitations which follow from the necessity of making money through equitable compensation for service rendered. We pretend to make every engagement yield a profit.

Another limitation reflects itself in the attitude which our men are sometimes forced to take with others, due not so much to disposition as to the time element. Time is the essence of much of our performance. If we did not put the highest possible value on it, we could never get anywhere. A great mill or shop will grind about a certain rate anyway. In an engineering concern, it is all man-work. If human effort is allowed to slow down, it will soon reach mediocrity, and then quickly come to a standstill. Diligence has little time for diplomacy. If we had plenty of time to look out of the windows and say pleasant things, there would be less hot telephoning and telegraphing, but we have to regard time all the time. If everything could be done leisurely, it could be done gracefully. We have no lack of appreciation for others or what they are accomplishing, but the pressure of the pace at which things now have to move reduces the opportunity to keep such appreciation always in evidence.

I have tried to illustrate as nearly as I could the spirit in which we carry on engineering operations, in which our purpose is not to do any one particular thing, but to supply competent engineering and constructive activity to do whatever needs be done.

THE PENNSYLVANIA RAILROAD TERMINAL

I have been asked to especially mention the Pennsylvania Railroad Terminal project and describe the engineering work we are doing on it. When the P. R. R. planned what is officially known as the New York Extension, which means all of the work east of the Meadows, or east of Snake Hill, they first appointed a board of engineers, or tunnel commission, which is composed of five engineers—Chas. W. Raymond, Wm. H. Brown, Chas. M. Jacobs, Alfred Noble, and George Gibbs. This commission made the plans and specifications of the tunnels and supervised the letting of contracts for them. They made Messrs. McKim, Mead & White the architects for the terminal station at Thirty-second street. They then appointed Mr. Alfred Noble engineer in charge of the heavy work, such as excavation, etc., at the terminal site. They made W. C. K. & Co. engineers for what is called the mechanical and electrical development of the undertaking, including all its service work and certain Long Island Railroad electrification. So the railroad looks to four parties—the tunnel engineers, the architects, Mr. Noble, and W. C. K. & Co. These four represent the effort which is producing the New York Extension. Later, the P. R. R. appointed as chief engineer of electric traction, Mr. George Gibbs, formerly first vice president of W., C., K. & Co. thereby providing an officer of the railroad through whom this work is now administered.

Specifically, our work comprises the electrification of certain divisions of the L. I. R. R. The power house that stands opposite Thirty-fourth street, which will be eventually about 100 000 horse-power, one-half of which is built and one-fourth of the power plant installed. It involves putting in another power house, of perhaps 30 000 or 40 000 hp, over on the meadows in New Jersey. Another service power plant at Thirty-first street, of 5 000 or 6 000 hp. Then there is the electrical transmission system from the New Jersey meadows across to Long Island, and the substations that go with it. It will be noted that the architects design the buildings, but not the engineering service features. This is our work and will comprise some thirty or more service functions, among which are the following: Air brake testing, air cleaning, baggage check delivery, baggage hauling, car heating, time and watchmen's clocks, drainage and plumbing, lighting, elevators, emergency room, dumbwaiters, fire and frost protection, garbage disposal, heating and ventilating, pipe and wire galleries and tunnels, power wiring and conduit work, refrigeration, steam for restaurant service, telegraph and telephone, train indicators, connections for train lighting, vacuum cleaning, and cooled, cold and hot water supply.

The terminal structure will be virtually a steel building with a granite shell, and the architects, at the requests of the P. R. R., made us their engineers to design the steel for the building proper, which we do for a fee from the architects. We are also the engineers for what is known as the "Easterly Portion", comprising that part of the excavation and bridging east of the westerly line of Seventh avenue, and which forms the V-shaped throats of approach to the easterly tunnels; also for the street bridging in the streets and avenues surrounding the building. The extent of this work may be appreciated from the fact that the terminal property extends from Thirty-first to Thirty-third streets and from Seventh to Ninth avenues, and for supporting the frontage over the excavation the width of a street all around requires some 21 000 tons of steel, all outside of the building. We have also had to do extensive work in connection with track plans, underdrainage, and many special features too numerous to outline, but all of which form a part of a complicated property of this type.

In general, about one-half of our work is constructive and the balance engineering service. We have already finished about $7 500 000 of work on this undertaking.

THE MAINTENANCE AND CALIBRATION OF SERVICE METERS*

WILLIAM BRADSHAW

THE modern integrating wattmeter has reached a stage in its development where the user's share of attention is reduced to a minimum. Nevertheless, careful and intelligent inspection and calibration are necessary and a never-failing source of revenue.

The maintenance bureau will have for its principal work a periodic inspection and test of its service meters. This can only be accurately and well done when properly systematized. Record cards, giving the head of the meter department at a glance the condition of the entire meter equipment, should be used.

CALIBRATION

The most efficient and cheapest method of making the periodic inspection and test consists in using such apparatus for the line test that the services of but one man capable of performing both inspection and test are required.

Secondary standards with which the line test can be easily and accurately made are now available in the form of special integrating wattmeters, variously known as test meters, master meters and portable standard integrating meters. The method of this line test consists in comparing the speeds of the moving element of the service meter and the standard. When used with discretion, it is the most accurate and reliable method available. The special integrating meter should never be considered as anything but a secondary standard and then only when its calibration is frequently checked by a reliable and accurate primary standard.

The laboratory work will consist, first, of test and repairs on service meters, the line test and inspection of which have indicated the need of more extensive repairs and calibration than can be made at the installation; second, of the care and calibration of the secondary standards. The most important and vital work of the maintenance bureau and laboratory of the central station is the proper use and calibration of the secondary standards and the care and use of the primary standard. If the standard is to be used for calibrating service meters of a different type than the standard, its calibration should include the change of registration for changes of frequency.

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*From a paper read before the National Electric Light Association, June 7, 1906.

The method of calibrating service meters by means of the rotary standard is so simple that many make the mistake of thinking that all that is necessary to make the proper check on the meter under test is to compare its speed with the standard If the service meter and standard are of the same type and capacity, a comparison of speeds indicates directly the accuracy of the meter under test; however, if of different types they will have different characteristics and hence give different registration for the same loads or for variation from normal of the voltage, frequency or temperature as shown by Figures 1 and 2.

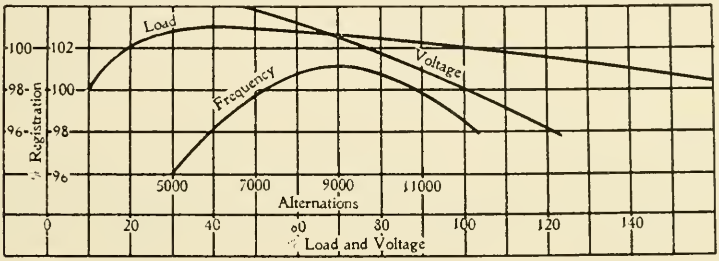

FIG. 1—CURVES ILLUSTRATING VARIATION. 5 AMPERE, 100 VOLT, 7200 ALTERNATION SINGLE-PHASE WATTMETER

Varying load, constant voltage and frequency.
Varying voltage, constant current and frequency
Varying frequency, constant current and voltage.

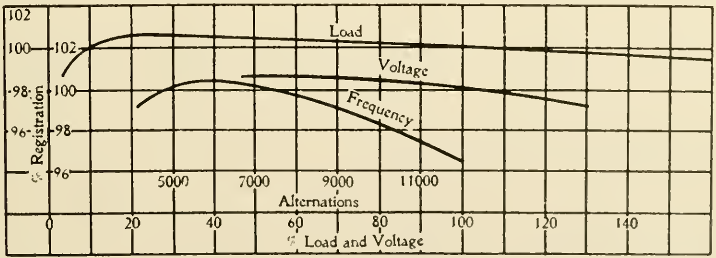

FIG. 2—CURVES ILLUSTRATING VARIATION. 5 AMPERES, 100 VOLTS, 7200 ALTERATIONS, SINGLE-PHASE WATTMETER

Varying load, constant voltage and frequency.
Varying voltage, constant current and frequency.
Varying frequency, constant current and voltage.

Corrections must be made in the reading taken during test for this different percentage registration or serious error will be made in setting the meter under test.

The loads at which the calibration of the service meter is made will also materially affect the accuracy of its calibration. The usual line tests are 0.1 and full-load. The full-load calibration being made by moving the permanent magnets and the 0.1 load calibration by the friction compensation. The closest possible setting by this means at 0.1-load may give an error of from 6 to 12 per cent. at 0.02-load and may even make the meter creep on voltage alone. Hence with the modern meter the line calibration at light load should be at 0.04-load or below.

The construction of the secondary standard will also affect the meter calibration. The standard should have several different capacities of series coils; their normal capacity corresponding to the normal capacities of the service meters in use. If these capacities do not agree there is another chance of error being made in calibrating the meter. A test should never be made with the meters so arranged as to give nearly full-load on the standard and light load on the meter being tested. Each type of integrating meter has a load curve that is not only different, but whose general shape is inherent and not a straight line. Hence the calibration of a meter by a load at one point of the curve and a reading on the standard at another point of the curve may mean an error in the setting of from 0.5 to one per cent., or even more.

If the several current capacities are obtained by separate coils for each capacity, it is practically impossible to get the same percentage registration for corresponding points on the load curve of each capacity. Allowance must be made for this difference or an additional error may be made in the meter setting. However, if there is but one series coil on the standard made up of a number of sections which are connected in series-parallel groups for different capacities, there will be no difference in the registration at corresponding points of each capacity load curve and hence no chance for error from this cause.

In selecting a secondary standard choice should be made of the meter which shows the best average performance for both load, voltage and frequency, and the limits of variation should not be greater than specified for service meters.

The primary standard determines the accuracy of the entire bureau's work and its reliability and permanency are of vast importance. The service meters have an inherent range of 75 times its smallest calibrated reading and the primary standards must cover the range limits of the entire line of service meters in use by the station.

The manufacturer or some standardizing laboratory should calibrate and maintain the primary standard. The difficulties encountered in both calibration and maintenance are best shown by a detailed description of the calibration of a line of instruments having the extreme ranges required and the requisite accuracy.

There are three classes of errors materially affecting the accuracy of the calibration of electrical instruments—errors due to unsuitable standards; errors due to vibration or unsteady load, and personal errors. In the method of calibration described an effort was made to reduce each of these classes of errors to a minimum.

The calibrations are made by comparison with standard cells and standard resistances, which are the fundamental standards for practical purposes. The regular method of calibrating ammeters by measuring the actual current in the instrument windings by means of one or more potentiometers and standard resistances, is also applied to wattmeter and voltmeter calibrations. The shunt circuits of the wattmeters and voltmeters require the same current for their operation, and this fact permits the use of instruments so made as to measure that particular value of current with the highest precision. The calibration of the wattmeters is made by two potentiometers, one for measuring the shunt and one the series current.

The potentiometer for measuring the shunt current is adjusted to measure exactly 0.1 ampere, and with the sensitive galvanometer used the slightest deviation from this value is readily detected. The rheostat used for controlling the shunt circuit is arranged for fine adjustment and is so placed that it can be readily operated by the man who reads the two potentiometers. The two sensitive galvanometers used with the calibration of wattmeters have concave mirrors which reflect the light from a Nernst glower on one scale close together, so that the observer reading the potentiometers practically controls the entire calibration.

The variations in the voltage of the standard cell for at least two years after they have been set up is practically negligible, seldom exceeding 0.01 per cent. After the voltage begins to vary appreciably the cell is discarded, owing to the liability of serious error being introduced at any moment.

The change in resistance of the wire used as standard resistance is even smaller than the percentage change of the voltage of the standard cell, and decreases with age. Manganin wire properly aged does not change its resistance more than a few thousandths of one per cent. in a period of several years.

There is practically no limit to the sensibility obtainable in such measurements, so far as the instruments are concerned. By using sensitive galvanometers and standard resistances with sufficient resistance to give a large drop of voltage with the current to be measured, the sensibility can be made such that a change of .0001 per cent. is as easily detected as a change of one per cent. is in ordinary commercial measurements.

The refinement obtainable in electrical measurements by use of potentiometers is well known, but they are not adapted for measuring alternating current or unsteady direct current. The ideal instrument for this service is one which approaches the accuracy of the potentiometer and allows the ease and quickness of manipulation necessary in the ordinary station test-room. The calibration of this instrument is made by direct comparison with primary standards of highest possible accuracy and it is used on either direct or alternating current.

The calibration of precision instruments is made with a degree of accuracy not obtainable anywhere except in a standardizing laboratory especially equipped for very accurate measurements. The current used is taken from storage cells of so much greater capacity than that required for the calibration that its use has no effect on the voltage of the cells used. In taking readings for determining the calibration curve, the meter index is always set to read on some even scale division and the current is then adjusted to produce this reading and measured by means of a potentiometer. Two operators are necessary; one to maintain the current constant at the amount required and the other to read the potentiometers. The whole process is really under the direct observation of the operator in charge of the potentiometers, since with uniformly divided scales the constants, obtained from taking readings at several points on the scale, must agree within the limits of the variations of the torque of the springs. Since there can be no sudden variation in the torque of the spring from a curve approximately varying directly as the deflection, it is evident that any reading which does not, with the other readings, make the slope of this curve gradual is wrong and must be checked. Thus, if either operator makes a mistake, the error is at once apparent from the readings of the potentiometer. The personal error is thus reduced to the extremely improbable chance of a series of errors following a uniform law throughout several consecutive readings.

The variable relation between the deflection of a spring and the torque required to produce it is not generally realized. In the use of ordinary current dynamometers, the assumption is made that the torque is directly proportional to the deflection and the constant is determined by averaging the quotient of the current divided by the square root of the deflection obtained from readings at several parts of the uniformly graduated scale.

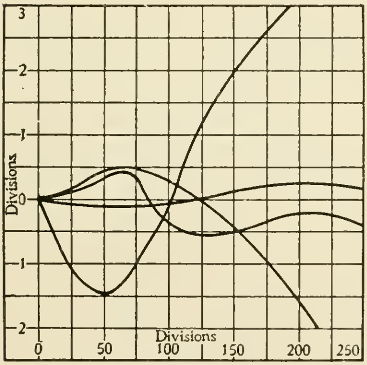

FIG. 3—CALIBRATION CURVES OF LINEMEN'S DYNAMOMETERS AND PRECISION METER

Such an assumption is accurate for some purposes. However, the error due to it varies with different springs and can be changed for any spring by changing the way in which it is clamped to the instrument and changing the shape of one or more turns.

The curves Fig. 3 are the calibration of several Siemens dynamometers and a precision instrument. The dynamometer curves represent checks on the manufacturer's calibration. The curve showing the minimum deviation from a straight line represents the average calibration on a commercial precision instrument.

This deviation from a straight line is due to several factors, including every detail in the design of the spring, spring holder and method of their mounting. In calibrating precision instruments the springs are adjusted to approximately the right strength and a trial calibration curve is made by observing the current corresponding to deflections at four or five points on the scale. A rough curve plotted from these readings indicates whether or not the calibration will be within the limits of the allowable variation. Experience enables the operator to tell from the preliminary curve what adjustment is necesssary to improve the calibration when the curve is outside the allowable limits.

Any curve having either large or small variations will repeat itself perfectly at any time, provided no re-adjustment of the springs is made inside the meter. Adjusting the springs so as to make the calibration curve practically a straight line does not affect the accuracy of the meter, except when readings are taken without reference to the curve.

Regarding the accuracy and sensibility of precision instruments, it is found that when the curve is once located, any point can be checked within 0.03 of a division, which is about 0.06 per cent. at one-fourth scale and 0.02 per cent. at full scale. These check readings must be made with steady current and corrections for temperature. However, their accuracy demonstrates that the only practical limit upon the accuracy obtainable with the instrument is the limit to which personal errors and the uncertainty due to fluctuating load can be reduced.

In addition to the calibration on direct current, thorough tests are made on alternating current to guard against any defect that might appear more prominent with alternating than direct current.

It has been the purpose to emphasize some essential points in the use of secondary and primary standards which are not generally understood or recognized. The difficulties of properly maintaining and calibrating the meter equipment of a central station are many and serious; nevertheless, they can be overcome by a properly organized and equipped bureau. The organization of the maintenance bureau will depend entirely upon the ability of its head. The equipment will be effective in producing accurate and permanent results in proportion to the liberality of the financial policy of the operating company. The energetic and progressive company will provide an equipment of primary and secondary standards which are free from the difficulties previously described and meet all the requirements for accurate and permanent work; such standards are available and have demonstrated their accuracy and permanency in commercial service. The proper equipment of standards and intelligent use of the same will always result in a material saving of the company's revenue.

FIRE HAZARD OF ELECTRICITY*

The following table, prepared by President L. B. Marks, and contained in his paper read before the Illuminating Engineering Society, gives an idea of the extent to which electricity is used for illumination:

APPROXIMATE COST OF ILLUMINATION TO THE CONSUMER PER ANNUM IN THE UNITED STATES (1905)

Electric light	Between	$100 000 000	and	$120 000 000
Coal and water gas	"	35 000 000	"	40 000 000
Natural gas	"	1 700 000		
Acetylene	"	2 500 000	"	3 000 000
Oil	"	60 000 000		

To reach a fair conclusion on the safety of electricity as compared with other light, heat and power mediums, a territory is selected in which electricity is widely represented. New York City is unquestionably one of the most densely electrically supplied territories in the world. Hundreds of miles of conductors traverse almost every avenue and side street of Manhattan and The Bronx and thousands of miles of wires radiate through each block of buildings; many structures alone extending over many acres and containing installations larger than are found in many towns throughout the country. Over 150 000 horse-power in motors, hundreds of thousands of arc and incandescent lamps, as well as heating appliances, are here supplied in one of the most congested centers of the country. Surely in this territory the extent of the electrical hazard can be fairly judged.

The following table has been accurately compiled from the official reports of the fire department of New York City for the years 1902-5, it being assumed that the field has shown its greatest growth during the last four years. In this table are represented not only the other illuminant risks, but common domestic risks as well. In order that a fair idea may be obtained of the danger of electrical equipment compared with that of other ordinary risks, it must be borne in mind that electricity might, with fairness, be compared as well to power mediums, such as boilers, furnaces, and the like, since in the item "Electric light wires, sparks from, or defective" not only is electricity represented as an illuminant, but as a very considerable source of power as well as of heat. Nevertheless, the total supply of electricity, considered as an illuminant alone, it can be readily seen, compares very favorably with other lighting mediums.

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* Extracts from the report of the committee on "The Fire Hazard of Electricity," read before the National Electric Light Association, June, 1906. Committee: H. C. Wirt, C. E. Skinner and A. A. Pope.

MANHATTAN AND THE BRONX. CAUSES AND LOSSES BY FIRES—WITH AVERAGES AND PERCENTAGE

	1902-1905		Av. Loss per Fire	% Total Fires	% Total Loss
	No. of Fires	Total Loss			
Ashes (hot); igniting woodwork, etc	113	$ 19,220	170	0.42	0.106
Chimneys, fireplaces, flues (defective), grates, etc.; heat from	1,710	216,005	126	6.36	1.197
Candles and tapers, carelessness in use of	1,248	107.303	86	4.64	0.594
Electric light, wires, etc., sparks from or defective	361	207,610	575	1.34	1.150
Kerosene, naphtha, benzine, gasolene, etc ; explosions or ignition of	352	178.408	507	1.31	0.988
Kerosene oil, used in starting stove fires	21	972	46	0.08	0.005
Gas—escaping and explosion of	687	39,603	58	2.56	0.219
" lights, igniting curtains, etc	894	91,761	103	3.32	0.508
" stoves, ranges, radiators, etc.; explosion of or heat from	468	56,799	121	1.74	0.315
Gas—total	2,049	188,163	92	7.63	1.042
Lamps—kerosene, gasolene, etc.; falling, breaking, upsetting, heat from	560	113,529	203	2.08	0.629
" alcohol, kerosene, etc., explosion of	266	23,795	89	0.99	0.132
Lamps total	826	137,324	166	3.07	0.761
Matches—carelessness in the use of	2,952	500,995	170	10.98	2.775
" gnawed by mice or rats	125	71,966	576	0.46	0.399
Matches, total	3,077	572,961	186	11.45	3.174
Sparks—from chimneys, stoves, stove-pipes, etc	640	110,794	173	2.38	0.614
Stoves—furnaces, stove-pipes, etc.; heat from	1,545	513,301	332	5.75	2.844
" furnaces, grates, etc.; hot coals falling from	114	16,368	144	0.42	0.091
" kerosene, gasolene, etc.; explosion of	6	3,100	517	0.02	0.017
" kerosene, gasolene, etc., falling, upsetting, heat from	180	23,205	129	0.67	0.128
Thawing out frozen water pipes, gas pipes, etc	335	53,548	160	1.25	0.297
Total number fires—all causes	26,878	$18,053,397	672	... ...	....

It can be seen that the percentage of damage due to lamps is well over that of electricity. It can also be seen at a glance that the percentage column for the entire four years with many risks, such as matches, stoves, kerosene, naptha, benzine and gasolene, gas stoves, defective chimneys and flues, are well up with and in some instances exceed the percentage of total losses attributed to electricity. In a more general comparison of the hazard of common and every-day risks, the relative safety of electricity is shown very clearly. The following table shows convincingly the place of electricity among other risks. As over eight times as many fires are caused by the handling of matches as are due to electricity; six, five, four and three times as many caused by risks most common in every house, the undoubted safety of the electric light medium for the modern building would seem to be demonstrated beyond question.

TOTAL FIRES—IN ORDER OF MAGNITUDE

Manhattan and the Bronx	1902-1905 (Inclusive)
1—Matches; carelessness in use of	2952
2—Chimneys, fireplaces, flues (defective) grates, etc.; heat from	1710
3—Cigars, cigarettes, pipes, etc.; smoking of	1690
4—Stoves, furnaces, stove-pipes, etc.; heat from	1545
5—Candles and tapers; carelessness in use of	1248
6—Children playing with fire, matches, etc.	1098
7—Gas-lights; igniting curtains, etc.	894
8—Lamps, kerosene, gasoline, etc., falling, breaking, upsetting, heat from	826
9—Gas; escaping and explosion of	687
10—Sparks from chimneys, stoves, stove-pipes, etc.	640
11—Gas-stoves, ranges, radiators, etc.; explosion of, heat from	468
12—Meats, fat, glue, etc.; igniting on stove	370
13—Electric light and wires	361

The following comparative statement of total losses shows the relatively small damage due to electrically caused fires considered with other common risks:

TOTAL LOSS IN ORDER OF MAGNITUDE

Manhattan and the Bronx	1902-1905 (Inclusive)
Stoves, furnaces, stove-pipes, etc.	$513 301
Matches; carelessness in the use of	500 995
Chimneys, fire-places, flues (defective), grates, etc., heat from	216 005
Electric lights, wires, etc.; sparks from or defective	207 610

THE EFFECT OF VOLTAGE AND FREQUENCY VARIATIONS ON INDUCTION MOTOR PERFORMANCE

GERARD B. WERNER

IT frequently happens that an induction motor, on account of special local conditions, is operated on a circuit of a voltage or a frequency different from that for which the motor was designed and rated. Under such circumstances, the performance will vary from the performance at normal operation. The following analysis deals with the effects on the motor performance caused by variations in the supply circuit:

1. *Over-Voltage*—Consider a 50 hp., 2-phase, 200-volt, 8-pole, 7 200 alternation motor with cage secondary. If this motor is operated on a 220-volt circuit, this 10 per cent-above normal voltage will slightly change the running characteristics.

The iron loss, which is proportional to a power of the induction nearly equal to 2, is increased 18 per cent., because the induction in the iron (which varies with the voltage) is 10 per cent. greater.

The effect of the change in voltage differs in different motors. In order to give definite figures, however, a particular motor is taken which is to be considered as typical and illustrative of the kind of effects which result from a change in the supply circuit rather than giving precise figures which apply to all motors.

The friction and windage will be roughly the same, as the speed changes only .8 per cent.

The primary copper loss will be smaller, because the current required for the same hp. is smaller.

The secondary copper loss is only 86 per cent, due to the lower slip, which, for the same hp. and apparent efficiency, varies inversely as the square of the voltage.

The aggregate losses are a little smaller, resulting in an efficiency .7 per cent higher than under rated voltage.

The magnetizing current, expressed in per cent of the total current, will for a given motor winding and magnetic circuit, be directly proportional to the square of the voltage (provided the iron is worked below saturation).

The leakage or reactance, expressed in per cent of the total induction, is inversely proportional to the square of the voltage (since the induction is increased, and the current is decreased).

The power-factor, which may be readily obtained from the relation:

$$\%\ \text{P.F.} = \sqrt{100^2 - (\%\ \text{magnetizing} + \%\ \text{leakage})^2}$$

is 1.2 per cent lower than under normal operation, due to these changes in the wattless components, directly consequent upon the increased voltage.

The apparent efficiency remains about the same.

The pull-out, or maximum torque, is 20 per cent greater on account of the reduced leakage.

The starting-torque is also increased 20 per cent.

It is thus seen (Table 1) that operation at 10 per cent over-voltage in a well-designed motor is quite satisfactory, resulting in higher pull-out and starting torques, higher efficiency, and lower temperature rise; but lower power-factor.

TABLE I.

50 HP—2 Phase—200 Volts—8 Poles—7 200 Alts.

	200 v.	220 v.	250 v.
Output, watts	37 300	37 300	37 300
Speed, r.p.m.	856	865	872
Slip, per cent	4.8	4.0	3.1
Pull-out, or maximum torque.	3.1	3.7	4.9
Starting-torque	2.1	2.5	3.0
Real Efficiency, per cent	87.8	88.5	88.8
Power Factor, per cent	93.2	92.0	86.8
Apparent Efficiency, per cent.	81.8	81.4	77.2
Iron Loss	1 100	1 300	1 650
Friction and Windage	620	620	620
Prim. Copper	1 700	1 410	1 230
Sec. Copper	1 880	1 550	1 180
Total Losses	5 200	4 880	4 680
Real Input	42 500	42 200	42 000
Magnetizing, per cent	23.6	28.5	41.0
Leakage, per cent	12.9	10.7	8.8
Apparent Input	45 700	45 800	48 300

NOTE.—Losses are given in watts; pull-out and starting torques are given in terms of full-load torque.

No general rule can be deduced to be applicable to all cases, as the efficiency under abnormal voltage will depend on the relative distribution of the losses; and the power-factor on the relative magnitude of the leakage and magnetizing currents. The power-factor generally decreases as the magnetizing is generally 1.5 to 3 times the leakage.

The foregoing analysis will also apply to the performance at fractional loads. The effect of over-voltage on the power-factor will be more marked; because, at half-load, e. g., the per cent magnetizing current is nearly double, and the per cent leakage is about halved. While over-voltage at full load increased the efficiency slightly, at half-load the efficiency will be reduced; because the iron and friction losses which are practically the same throughout the range of load, are much in excess of the copper losses.

The effect of over-voltage exceeding 10 per cent will result in a wide variation from the performance at rated voltage (Table I). At 250 volts the magnetizing current is increased to 41 per cent, the iron being worked beyond the bend in saturation curve; resulting in a greatly reduced power-factor. While the starting and overload capacity (pull-out) are increased, the higher iron loss would jeopardize cool operation.

2. *Under-Voltage*—Taking another representative motor we will note the variation in the performance produced by running at 91 per cent and 73 per cent of rated voltage (Table II).

TABLE II.

75 HP—3 Phase—550 Volts—6 Poles—3 000 Alts.

	550 v.	500 v.	400 v.
Output, watts	56 000	56 000	56 000
Speed, r.p.m.	478	473	460
Slip, per cent	4.3	5.2	8.1
Pull-out	3.6	3.0	1.8
Starting Torque	2.5	2.6	1.2
Real Efficiency, per cent	89.9	88.6	83.8
Power Factor, per cent	93.3	94.0	93.3
Apparent Efficiency, per cent.	83.8	83.3	78.3
Iron Loss	1 100	930	600
Friction and Windage	400	400	400
Prim. Copper	2 300	2 810	5 000
Sec. Copper	2 500	3 070	4 930
Total Losses	6 300	7 210	10 930
Real Input	62 300	63 200	66 900
Magnetizing, per cent	24.9	20.5	12.3
Leakage, per cent	11.1	13.6	22.7
Apparent Input	66 800	67 200	71 800

When running at 500 volts the efficiency is somewhat lower

The iron loss is reduced 15 per cent. by the lower density in the iron.

The friction and windage is unchanged.

The primary copper loss is 22 per cent larger, due to increased current, and the secondary copper loss is about 20 per cent greater, due to larger slip.

The power-factor is improved .7 per cent by the smaller magnetizing current, but the pull-out is decreased 17 per cent by the larger leakage.

The starting torque and apparent efficiency are about the same.

So that, operation at 10 per cent under-voltage is quite satisfactory, provided the starting and pull-out torques are adequate for the work required; and the design liberal enough, so that the greater losses do not result in an excessive temperature rise.

If the voltage is reduced 27 per cent, that is, if the e. m. f. be 400 factor at fractional loads will be bettered several per cent by a drop in voltage. At 550 volts the power-factor is 85.5 per cent at half-load; at 500 volts, 89.2 per cent. The efficiency at half-load, however, is lowered by a drop in voltage.

If the voltage is reduced 27 per cent,that is, if the e. m. f. be 400 instead of 550, the efficiency is greatly reduced (83.8) per cent), and the pull-out and starting torques are about halved, although the power-factor is about the same. Only two-thirds of the hp capacity, approximately, or 50 hp could be developed, because of the excessive temperature rise, consequent on the large copper losses.

3. Lower Frequency—Table III shows the performance of a 50 hp, 7 200-alternation motor, when operated on 50 cycles.

TABLE III.

50 HP—2 Phase—200 Volts—7 200 Alts—8 Poles.

	7 200 Alts.	6 000 Alts.
Output, watts	37 300	37 300
Speed, r.p.m.	856	713
Slip, per cent	4.8	4.8
Pull-out	3.1	3.7
Starting Torque	2.1	2.5
Real Efficiency, per cent	87.8	87.6
Power Factor, per cent	93.2	92.0
Apparent Efficiency, per cent	81.8	80.7
Iron Loss	1 100	1 320
Friction and Windage	620	430
Prim. Copper	1 700	1 750
Sec. Copper	1 880	1 880
Total Losses	5 200	5 380
Real Input	42 500	42 680
Magnetizing, per cent	23.6	28.5
Leakage, per cent	12.9	10.9
Apparent Input	45 700	46 300

On 6 000 alternations, the iron loss is 20 per cent higher, due to 20 per cent higher induction in the iron at 83 per cent of normal frequency.

The friction and windage losses (which vary approximately as the square of the speed) are 30 per cent less.

The copper losses remain practically unchanged, since the output and voltage are the same.

The resulting efficiency is about the same as that at normal frequency.

The magnetizing current is increased at the higher induction; and the per cent leakage is lower (the leakage flux being the same for the same current).

The resulting power-factor is slightly lower.

For the same hp output at 83 per cent of rated speed, 120 per cent of normal torque is required. Since the torque is proportional to the product of the secondary flux and secondary current, at 120 per cent flux the secondary current should be the same as before. The latter varies with the secondary flux, and the secondary frequency; so that the secondary frequency in r.p.m. is 83 per cent, i. e., the slip is the same in per cent as before.

The pull-out and starting torques are both 20 per cent greater.

A 7 200 alternation motor can thus be successfully operated on 6 000 alternations with about the same efficiency, slightly lower power-factor, increased starting torque and pull-out, and the obvious reduction in speed.

On 3 000 alts., the operation of a 60-cycle motor is impossible at *rated voltage,* on account of the high induction required to produce the necessary torque for the same output and 42 per cent normal speed. At 2.4 times the normal density in the iron, the iron loss is approximately doubled, and the magnetizing current would be nearly as great as the energy component at the resulting high saturation. The resulting current would make the copper losses prohibitive. In a word, the motor is too small for the torque required.

4. Higher Frequency—On 3 600 alts., a 3 000-alt. motor may be operated successfully with about the same efficiency, improved power-factor; but decreased starting and pull-out torques (Table IV).

The friction and windage is about 45 per cent higher; the iron loss 13 per cent lower; and the copper losses about the same.

The decreased magnetizing current (due to the lower induction) raises the power-factor .8 per cent.

The higher leakage lowers the pull-out and starting torque about 17 per cent.

The per cent slip remains the same; since the full-load torque is 83.3 per cent of the full-load torque at rated voltage, and the frequency is 120 per cent of rated frequency.

On 7 200 alts., or 2.4 times normal frequency, cool and efficient operation is obtained, but with very poor starting and pull-out torques.

The iron loss is approximately halved (the density in the iron being 42 per cent).

The friction and windage are nearly six times as large.

The copper losses are practically unchanged.

TABLE IV.

75 HP—3 Phase—550 Volts—6 Poles—3 000 Alts.

	3 000 Alts.	3 600 Alts.	7 200 Alts.
Output, watts	56 000	56 000	56 000
Speed, r.p.m.	478	574	1 148
Slip, per cent	4.3	4.3	4.3
Pull-out	3.6	3.0	1.5
Starting Torque	2.5	1.9	.5
Real Efficiency, per cent	89.9	89.9	88.1
Power Factor, per cent	93.3	94.1	92.8
Apparent Efficiency, per cent.	83.8	84.6	81.8
Iron Loss	1 100	960	540
Friction and Windage	400	580	2 300
Prim. Copper	2 300	2 280	2 400
Sec. Copper	2 500	2 500	2 500
Total Losses	6 300	6 320	7 740
Real Input	62 300	62 300	63 700
Magnetizing, per cent	24.9	20.6	10.2
Leakage, per cent	11.1	13.2	27.2
Apparent Input	66 800	66 300	68 500

The power-factor is lowered .5 per cent on account of the high leakage; although the magnetizing is only 10.2 per cent.

The low pull-out might result in frequent stalling on momentary over-loads; and the low starting torque might not be sufficient for a large friction load.

5. *Changes both in Frequency and Voltage*—From the last two examples of the effect of variations in the alternations of the supply circuit, it is plain that a certain change in the voltage should accompany a change in the frequency. The size of a motor required for a given work is governed by the hp per 100 rpm., so that if a 50-hp, 7 200-alt. motor is to be run on 3 000 alts., i. e., at 41.7 per cent normal speed, the maximum output at which the machine can be rated, allowing the usual over-load margins of reserve, will be about 20 hp. To get approximately the same performance, however, the voltage should be reduced in proportion to the frequency, i. e., 83.3 instead of 200 volts. Table V illustrates the case.

It will be seen that although the iron loss and friction losses are low, the copper losses lower the efficiency considerably. The latter are due to the high slip (which for the same torque varies directly as the frequency, and inversely as the square of the voltage).

TABLE V.

50 HP—2 Phase—200 Volts—8 Poles—7 200 Alts.

	200 v. 7 200 Alts.	83 v. 3 000 Alts.
Output, watts	37 300	15 500
Speed, r.p.m	856	332
Slip, per cent	4.8	11.5
Pull-out	3.1	2.75
Starting Torque	2.10	1.95
Real Efficiency, per cent	87.8	77.0
Power Factor, per cent	93.2	93.6
Apparent Efficiency, per cent	81.8	72,1
Iron Loss	1 100	400
Friction and Windage	620	93
Prim. Copper	1 700	2 160
Sec. Copper	1 880	2 010
Total Losses	5 200	4 660
Real Input	42 500	20 160
Magnetizing, per cent	23.6	20.9
Leakage, per cent	12.9	14.6
Apparent Input	45 700	21 500

With the same induction, the magnetizing current is the same in amperes, but the per cent is lower on account of the lower apparent efficiency.

The higher leakage reduces the pull-out somewhat.

The power-factor is about the same.

Then again, although the losses can be dissipated, the temperature rise is higher, on account of the less effective ventilation at the lower speed.

As a second instance of operation at different voltage and frequency, consider the 75-hp, 3-phase, 550-volt, 6-pole, 3 000-alt. motor on 7 200 alts. Here the speed is nearly 2.5 times as great. If it is desired to keep the *same torque* and raise the hp to 180, the voltage should be changed in proportion to the frequency, i. e., to 1 320, to give the same performance. If the *same horse power* is desired the voltage should be changed as the square root of the frequency, or 852 (Table VI).

For the *same torque,* the induction remains the same, so that the magnetizing current is unchanged in amperes and per cent, since the voltage is raised in the same proportion as the output.

The leakage is also the same, since the induction and current are the same.

The copper losses, in watts, are very nearly the same.

The iron loss is higher, at the higher frequency; and the friction losses are nearly six times as great.

The efficiency is improved by the small secondary copper losses;

but the starting torque (which is proportional to the slip) is low.

It is seen from this performance that the motor is good for 200 hp at 7 200 alts.

TABLE VI.

75 HP—3 Phase—550 Volts—6 Poles—3 000 Alts.

	550 v. 3 000 Alts.	1 320 v. 7 200 Alts	852 v. 7 200 Alts.
Output, watts	56 000	134 300	56 000
Speed, r.p.m.	478	1 175	1 175
Slip, per cent	4.3	2.0	2.0
Pull-out	3.6	3.7	3.6
Starting Torque	2.5	1.5	1.5
Real Efficiency, per cent	89.9	93.0	90.8
Power Factor, per cent	93.3	93.2	93.3
Apparent Efficiency, per cent.	83.8	86.7	84.8
Iron Loss	1 100	3 000	1 300
Friction and Windage	400	2 300	2 300
Prim. Copper	2 300	2 200	940
Sec. Copper	2 500	2 740	1 140
Total Losses	6 300	10 240	5 700
Real Input	62 300	144 500	61 700
Magnetizing, per cent	24.9	25.7	25.1
Leakage, per cent	11.1	10.8	11.0
Apparent Input	66 800	155 000	66 200

For the *same horse power,* the magnetizing and leakage are the same, since both the current and the induction are 35 per cent lower. The copper losses are lowered, and the iron loss is raised. The efficiency is about 1 per cent higher; the power-factor and pull-out about the same; but the starting torque is lowered by the small slip.

A CHART FOR USE IN MAGNET DESIGN

L. F. HOWARD

IN DESIGNING electromagnets for different conditions it is often necessary to change the size of the wire with which a given electromagnet has been wound and to know the voltage which would be required to give the same number of ampere-turns with the new winding. The reverse conditions are also often encountered.

The chart shown in Fig. 1 was designed to give a quick and convenient means of obtaining the size of wire, or voltage, in either of the above cases.

The principle of its construction will be understood from a consideration of the following statements:

If an electromagnet has one turn of wire of a given size, and a certain voltage is applied, the ampere-turns will be equal numerically to the number of amperes flowing or the applied voltage divided by the resistance of the wire. If the number of turns is varied, keeping the mean length of turn and voltage constant, the resistance of the winding will increase, and the amperes decrease in proportion to the number of turns. Consequently the ampere-turns will remain constant.

If we substitute for the one turn first taken, one turn of another size, then in order to get the same number of amperes flowing, and hence the same ampere-turns, we must vary the voltage in direct proportion to the ratio of the resistance per unit length of the two sizes, or what is the equivalent, in the inverse ratio of their areas as expressed in circular mils.

The chart is designed primarily to obtain this ratio. It is divided vertically by lines corresponding to the divisions of the ordinary slide rule, i. e., the numbers on the lowest horizontal line are located at distances from the left-hand end of the scale corresponding to the mantissae of their logarithms.

Just above the horizontal line *C. M.* are numbers representing the B. & S. sizes from 10 to 29 inclusive, placed opposite the sequence of figures, as read on the lowest line, which express their area in circular mils. The figures below the line *C. M.* are the characteristics of the logarithms of the circular mils of the sizes opposite which they stand.

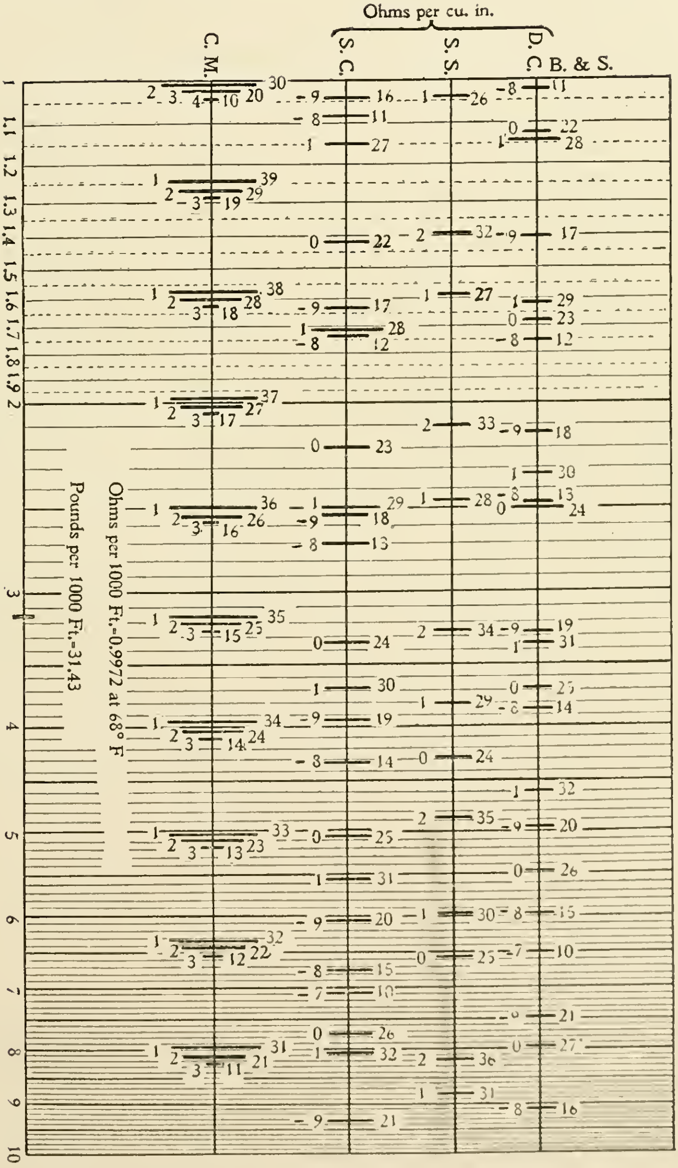

FIG. 1—CHART FOR MAGNET DESIGN

In a similar manner are plotted the theoretical ohms per cubic inch for single cotton, single silk, and double cotton covered wires for the B. & S. sizes most commonly used, five-mil insulation being assumed for the single cotton, two mils for sizes 24 to 31 inclusive, and one and three-fourths mils for sizes 32 to 36 inclusive for the single silk, ten mils for sizes 10 to 12 inclusive and nine mils for sizes 13 to 32 inclusive for the double cotton. About one per cent. allowance is made for over-size.

As an example of the use of the chart, assume that a magnet is wound with No. 12 B. & S. wire and operates on 112 volts, and it is desired to find the voltage required if the magnet is rewound with No. 25. On the line *C. M.* take the distance between the figures 12 and 25 with a pair of dividers or pencil and paper. Beginning at the left, lay off this distance on the lowest line and we get 20.4, the ratio of voltage required to given voltage; or, lay the distance off to the right of 112 and read the required voltage, 2 280, direct. The difference between the characteristics opposite 25 and 12 added to the characteristic of the logarithm of 112 determines the number of figures to the left of the decimal point.

In the above example, the larger size wire No. 12, lay to the right of the smaller. If No. 18 had been assumed instead of No. 12, the reverse would have been true, and we would have laid off the distance between No. 18 and No. 25 to the left of ten on the lowest line, obtaining the ratio 5.07. If the new voltage is required direct, it would be obtained by laying off to the left of 10 on the lowest line the *difference* between the distance as taken on line *C. M.* and distance 0 to 112 on the lowest line, the result being 568.

The ratio of the resistances of the two windings, assuming the same winding space is used, is found by laying off on the lowest line the horizontal distance between the sizes on the lines marked for the corresponding insulation, paying proper attention, of course, to the characteristics.

If the resistance of the magnet in the first example is 36 ohms, and the winding No. 12 double cotton covered wire, and it is desired to use single silk insulation on the No. 25 wire, the resistance of the new winding would be found as follows:

Place one point of the dividers on the line *D. C.* opposite the figure 12 just above the line. Place the other point of the dividers on the same line at its intersection with a vertical line which would pass through the point just under the figure 25 on the line *S. S.* This distance laid off to the right from the left-hand end of the lowest line will bring the right-hand point of the dividers on the sequence of figures 373. The difference of the characteristics is 2, and this increased by 1 gives the number of places to the left of the decimal point, the required ratio being 373.

The diameter in mils of any size on the chart can be obtained by laying off on the lower line one-half of the abscissa on the line *C. M.*, laying it off to the right of *O* when the characteristic for the size is even and to the right of the mark at *316* when it is odd.

For example: Required the diameter in mils of No. 25. Take half the distance from 0 to 25 on the line *C. M.* and lay it off to the right of 0 on the lowest line. The right-hand point of the dividers will rest on the sequence of figures 179. The characteristic opposite 25 is 2. Dividing this by 2 we get 1, which increased by 1 determines that there will be two places of figures to the left of the decimal point, i. e., 17.9 is the diameter in mils required. If we had wished to find the diameter of No. 18, opposite which is the odd characteristic 3, we should have taken half the distance between 0 and 18 on the line *C. M.* as before, but should have laid it off on the lowest line to the right of *3.16*, obtaining the sequence of figures 403. In determining the number of places to the left of the decimal point we divide the characteristic opposite 18 by 2, and increasing the *integral* part of the dividend by 1 as before, we get 40.3, the required diameter.

This chart could be extended, of course, to apply to larger sizes of conductors, such as are used for large field magnets.

POINTS ON CENTRAL STATION WIRING

W. BARNES, JR.

IN all electrical installations the power cables running from the generator to the switchboard, the connection that is made to the terminal board on the generator and to the stud on the controlling switch and circuit breaker, are of more importance than any other part of the station wiring. Should a breakdown occur at any of the above-mentioned places it has a great effect on the total output of the plant. If it is not possible to cut out a unit for a short time and let the load be carried on the balance of the generators, the result will soon be felt over the entire system. As trouble from faulty connections will only show up when the plant is running at its maximum load and when the power is needed the most, it is of greatest importance that the work of connecting up the power cables be done in a manner that will leave no room for doubt as to their behavior under heavy overloads.

In soldering large or small terminals to cables a few points are well worth remembering to obtain the best results. Terminals should be well tinned inside before using. A good way to do this is to put the terminal in a pot of hot solder until it is well heated, then withdraw the terminal and apply the acid or soldering paste to the parts to be tinned, and then fill the terminal with hot solder and pour out immediately. This will almost always insure a good job of tinning. If it does not, repeat the operation being careful that the acid and soldering paste does not touch any part of the terminal other than that which is to be tinned. If the terminal in question is too large to be submerged in a pot of solder, good results can be obtained by heating the terminal, applying the acid or soldering paste and then rubbing the inside of the terminal with "stick" or "wire" solder. A terminal should never be used until all of the inside is well coated with solder.

Cables as well as terminals should have their ends tinned before using. Perhaps the best and quickest way to do this is to dip the end of the cable in the acid or rub well with soldering paste, then dip the cable in a pot of hot solder. Should any of the end of the cable remain untinned, repeat the operation until there can be no room for any doubt as to a good job, shaking off any solder that may cling to the cable.

The proper location of cables is very important. Cables should be kept as far as possible from steam pipes or where there is escaping steam or leaking water pipes. Excessive heat will rot the insulation and also leave the cables in such shape that they are a danger to men making repairs on any part of the power house equipment located near the cables. Water is a bad thing near cables, as there is always a chance of getting a ground due to "surface leakage." The above points apply more to cables which are supported by iron or wooden brackets than to cables which are run in clay or iron conduit.

The principal points to remember in case the cables are run in conduit are to see that there are no bad joints where water or any foreign matter may enter; also, that there are no burrs in the conduit where the pieces are joined together. The best time to take off any burrs that may be left after a pipe is cut, is before the pipe is removed from the vise.

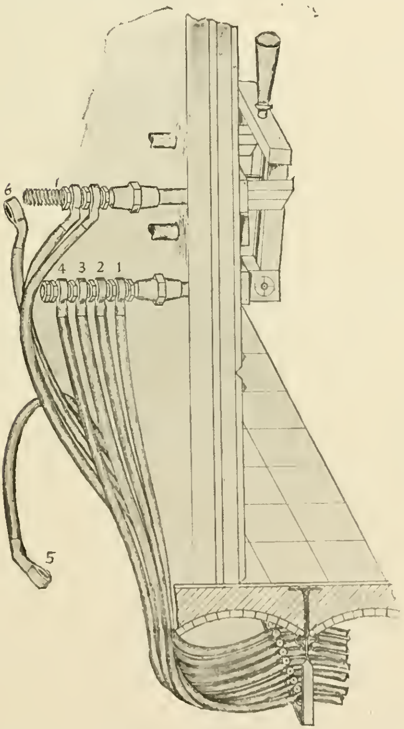

FIG. 1—SHOWING METHOD OF CONNECTING CABLES TO SWITCHBOARD.

We have considered briefly the importance of the wiring, method of tinning terminals and cables, also the location of the cables and a few points to watch when conduit is used. Let us now assume that we have the cables in place and tinned ready to solder the terminals to the cable and fasten them to the circuit breaker or switch stud. One thing to watch is to see that the cables coming from the conduit or bracket hangers have the same amount of slack in them, so that when they are soldered and fastened in place they will all be in line. The safest way to accomplish this is to solder the terminal which is to be nearest the switchboard and on the lowest stud first. As for example in Fig. 1, terminal No. 1 should be put on first. Then Nos. 2, 3 and 4. If possible they should be soldered and put in place one at a time. That is, do not try to cut all the cables to just the right length without having any of them soldered in place. Great care should be taken that there are no nicks or burrs on the nuts for the studs, and that they are well cleaned with emery cloth and wiped with a dry piece of waste before being run on the stud. A good way to clean the contact surface of a nut or terminal is to wrap emery cloth over a block of wood large enough to be gripped by the hand and rub the terminals well; or lay a full size piece of emery cloth on a board and rub the terminal or nut on it. If the emery cloth is held in the hand, there is a tendency to rub off the surface at the edges and thus loose part of the contact surface. If possible, the hands should not come in touch with the contact surface after the nut has been rubbed with emery cloth and wiped with a dry piece of waste. This last is a precaution one would hardly think necessary but, as the workmen's hands at this time are apt to be very dirty and greasy, it is best to take this precaution to insure a clean contact. Wherever possible, a terminal should be placed upside down when it is ready for the cable to be soldered into it, as shown in Fig. 1 terminal No. 5. Heat the terminal well and have it one-half or two-thirds full of hot solder. Then insert the cable slowly, keeping a torch applied to the terminal. If possible, the end of the cable should be heated first in a pot of hot solder until it is up to the temperature of the solder before placing in the terminal. If the stud is near the floor and the shortness of the cable will not allow it to be bent back, the cable should be pulled back in the cellar and terminal put on there. If it is a job where conduit is used and the cable can be pulled back far enough to allow for this, it should be done. If there is no way of soldering the terminal while upside down, then drill a small hole through the upper part of the terminal, place the terminal in position on the cable, wrap the terminal and cable well with tape and pour the solder in through the hole in the top of the terminal, keeping a torch on the top of the terminal until you are sure that the solder has had a chance to work its way all through the cable. The objection to this method is that one never knows when the cable and terminal are well filled with solder, for when one thinks he has it well filled, he generally finds the solder running out through the tape onto the floor. One other point to watch when the terminal is soldered to the cable and it is ready to put in place, is to see that it goes on the stud so as to have the contact surface of the terminal parallel with the contact surface of the nut. Note in Fig. 1 terminal No. 6 should be straightened up before going on the stud. If this point is carried out, it will insure perfect threads and no undue strain on the marble panel when the nut is tightened up.

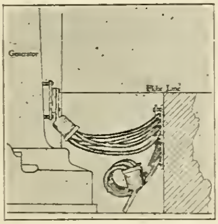

FIG. 2

Fig. 2 shows a machine terminal with four cables soldered in it at the same time. In case of heavy work, where more than one cable is is to be soldered into the terminal and where the terminal is to be turned upside down, it is best to take one cable at a time. Cut it the right length and place in the position it will be when finished. Hold the cable in place by wrapping bare wire around the cable and terminal and tieing them together. Do this with each cable and as soon as they are all in place, tie them together and tie to the terminal. On a set of four large cables, it will require a good deal of binding wire to hold the cable in place so that the terminal can be turned over without having the cables get out of position.

After the cables and terminal have been properly tinned and tied together and the terminal is upside down, heat the terminal well with a torch (several will be required if the terminal is a large one), and then pour in the solder, giving it a chance to settle and shrink. Keep pouring in the solder until you are sure it has worked its way to the bottom of the terminal, all through the cable and is flush with the top of the terminal. In this way one can be assured that, if the terminals and cables were properly tinned, there will be no trouble with the terminal carrying its load, provided the terminal itself and the cable are large enough. When placing the terminals on the terminal board, care should be

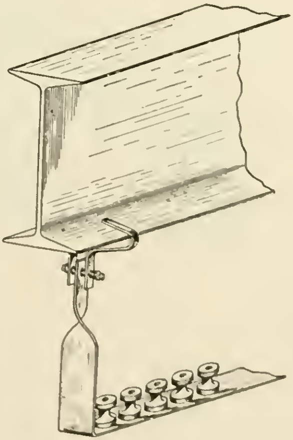

FIG. 3

taken to see that the contact surface of the terminals are parallel to the contace surface of the machine, so as not to allow any twisting strain on the marble or slate terminal slab. Often on a job of wiring in central station work, the engineer has to get his cables in as best he can, and is unable to take the time to buy any of the special insulators and insulator brackets that are manufactured for heavy central station wiring. Fig. 3 is a good example of what can be made for a hanger for cables where one has to depend on his own sketches and a small blacksmith shop in which to do the work. This style of bracket or hanger is so simple that it will need no explanation. The size of the material used depends on the number and size of cables used and the spacing of brackets or hangers. In case braces are to be fastened to a wooden frame work, the top can be changed to suit conditions. For running cables along a brick wall, an arrangement such as shown in Fig. 4 can be used. All that is required in this case are the necessary expansion bolts and blocks of hard wood. The size of bolts and wooden blocks depends on the size and number of cables used. Wooden blocks should have two or three coats of insulating paint or varnish before being put in place.

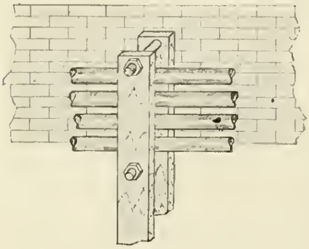

FIG. 4

EXPERIENCE ON THE ROAD

J. W. SWEENEY

UNLOADING A LARGE ROTOR

A SHORT time ago a 6600 kw alternator was to be installed in a certain power plant. The weight of the revolving field was 42 tons. The field was shipped on a flat car which had an opening or well in the middle, thus allowing the bottom of the field to come about three and one-half feet below the surface of the car. In order to unload the field by ordinary methods it would obviously be necessary to raise the field about three and one-half feet in order to clear the car. This would involve the erection of powerful hoisting apparatus, which would have been quite an undertaking. Consequently, the car was unloaded from the field by lifting one end of the car from its truck so that the field could be rolled out from beneath the car. The field was thirteen and one-half feet in diameter. The method of procedure is shown in Fig. 1. The plan worked smoothly and easily without a mishap.

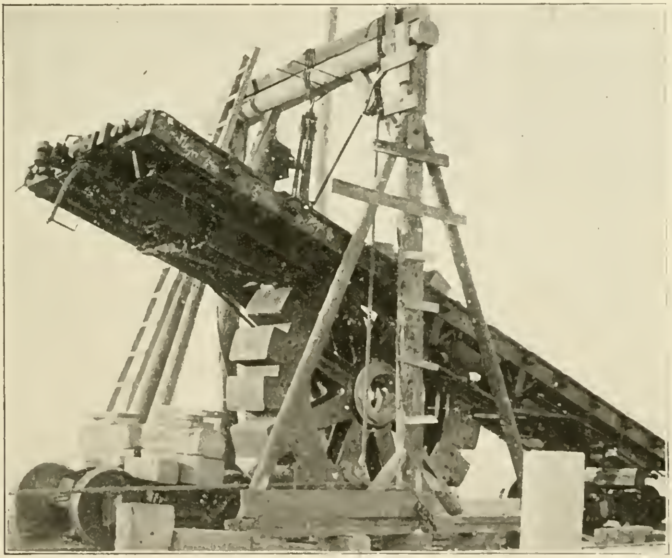

FIG. 1—UNLOADING A 42-TON ROTOR

The field was afterward turned over on its side, and slid several hundred feet down an incline. This incline was as steep as forty-five degrees in some places. The particular difficulty in this undertaking was figuring out how to handle the job, the carrying out of the work was comparatively easy.

When the apparatus reached the power house it was handled in the ordinary way by a large crane.

W. G. McCONNON

EXCITER SPEED TOO LOW

The writer recalls a very urgent and hurried trip he made to Texas some time ago to look after a complaint that under load a certain machine would not hold up voltage. This was manifestly the case when a trial of the machine under load was made. On investigation it was found that the exciter was not running up to speed and hence not giving the normal field current. A temporary wooden pulley was made for the exciter of a size to give proper speed, and no further trouble was experienced.

FIELD COILS INTERCHANGED

Quite recently a very serious complaint was made that a new 75 kw two-phase generator would not generate, and the armature coils were short-circuited, two conditions which, if true, most road men would be most thankful to know might exist simultaneously. An examination of the machine indicated something wrong with the field coils. The owner of the plant had installed the machine himself, and had placed No. 6 coil in place of No. 9 coil. This may seem to be a very radical mistake, but we can feel some sympathy for the man who makes it. He had evidently never been instructed that a — on one side of a certain character means one number and the same — on the other side means something else. After changing the coils to the proper poles, the machine worked entirely satisfactorily. The short-circuited armature was evidently a matter of imagination.

A WRONG ADJUSTMENT OF THE SERIES SHUNT

The two cases just mentioned indicate that it is not necessary to assume in all cases that deep and impenetrable mystery exists in all trouble cases just because the correspondence indicates as much. A case which illustrates rather hasty and incomplete work on the part of the road man, probably a relatively inexperienced man, was recently called to the writer's attention. A direct-current railway generator of about 300 kw capacity, which was getting excellent care generally, would get to sparking so badly that in a short time the commutator would be in such shape as to necessitate turning it off. After this had happened a number of times a man was sent to investigate the trouble. It was found that the machine had an unusual over-compounding effect, due to the series winding, and as the voltage on the line had to be limited to 550 volts, the shunt field was made very weak, the result being that the machine voltage dropped very low when no load was on, but went to full voltage when load was applied. The effect of the great change of the voltage was to start sparking at the brushes. While this did not appear very serious on a new and smooth commutator, it would soon become so bad that the commutator would be beyond control of the station man. The remedy was, of course, to shunt the series field windings until the machine would work at constant voltage at all loads. The men who erected this machine probably obtained very satisfactory results when running without load, with a certain field strength due to setting his field rheostat at a certain point, and he also probably obtained equally satisfactory results with some other position of rheostat when running under load, but he failed to note that the operating conditions on his machine and field rheostat, which would necessarily have to remain constant in service, were not the same in the two cases. It is never safe to assume that because a machine works entirely satisfactorily at one load, it will do so at all other loads. The only safe test is to set the rheostat for the voltage required, and then run the machine up and down the range of load several times, and watch results closely. A water rheostat made of a few barrels fitted up with iron plates and salt water will give a ready means of getting a sufficient load for testing.

MOISTURE IN TRANSFORMERS

Probably there is nothing for which a road man must be more on his guard than to prevent moisture getting into high-tension transformers. The writer, during the last few weeks, has been called upon to investigate the failure of two 1 500 kw, 2 200 volt transformers which gave out simultaneously when working on a relatively light load. In this case three transformers were working in delta connection and so far as known no switching was being done on the line at the time of failure and no known disturbance took place previous to the break-down. While no direct cause could be found for the break-down occurring at the time it did, it was found that there was moisture in the oil and insulation. It was said that at the time the transformers were put in service, the cases were not cleaned, and it is thought that rain had gotten into the cases. Some of the cases may have been left open and collected water from rain at the plant. Whatever the cause of so much moisture, it indicates that not sufficient care was taken to ascertain that no moisture was present when the transformers were set up. Out of the fourteen transformers, six had been injured apparently from the same cause.

Moisture may get into the transformers in some other unexpected ways. The writer some time ago received six oil-insulated, water-cooled transformers for a large plant in the west which he was erecting. These arrived late in the season after cold weather had begun. Three transformers were to be gotten ready for service first. The first one of these had been placed in its case and the cover and cooling coil had been put in position. While the covers and cooling coils of the other transformers were on the station floor, it was noticed that water was dripping from one of the coils. An investigation showed that the brass pipes in this set of cooling coils contained water. This had frozen in coming over the mountains and cracked the brass pipe in several places. A further investigation showed three cooling coils out of the six were damaged by the water freezing in them and splitting the pipes. It was rather fortunate that this condition of affairs was discovered before the coils were placed in their cases. In repairing these coils it was necessary to remove the brass cooling pipes from the covers and separate the turns of the coils as far as possible and repair each pipe by itself. The repairs consisted in wrapping the pipe wherever it was split with soft copper wire, and then carefully soldering the wrapped portion. After repairing in this manner a pressure gauge and force pump were obtained and the coils put under air pressure. When they held the pressure for a reasonable length of time they were passed as safe.

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Motors in Steel Mills

In connection with the article by Mr. Wiley on the 1 500-hp motors lately installed in Roll Mill No. 3 at the Edgar Thompson Steel Works, it is interesting to note the progress of electric power development for steel mill service which has all taken place in the last fourteen or fifteen years. Between fourteen and fifteen years ago the first installation of electric power for use in steel mill work was made in one of the mills of the Pittsburgh district. The original purchase consisted of a 75-kw belt driven generator and a few small motors. The success of this equipment was such that it was very shortly supplanted by two 187.5-kw belt driven generators. Within about five years from the date of the original installation two 400-kw engine driven generators were added to the installation; within two or three years thereafter two 800-kw engine driven generators, and still later two 1 500-kw generators were added; and when the other apparatus now arranged for is installed the plant will have a capacity fully one hundred times that of the original installation, made only about fourteen years ago.

As would naturally be expected the growth in the amount of electric power used has been largely due to a broader scope of purposes for which it has been employed. At first motors were looked upon as a means to an end for supplying such minor power as was required at points where steam was not available, i. e., for certain small conveying tables and a few traveling cranes, the steam engine receiving the preference where steam could be obtained and the engine made to do the work. The motors, however, gradually proved to be the more reliable, and not only more reliable but vastly more economical.

Additional uses were rapidly found for electric motors in connection with steel mill work. All conveying tables were gradually equipped with motors. Shop cranes and yard cranes were added. Engine driven shears were thrown out and electrically driven shears substituted. Electrically driven charging machines superseded hand charging, until at the present time nearly every modern steel mill uses electrical power for all operations except for driving the main rolls.

The step taken by the Edgar Thompson Works in installing the two 1 500-hp motors referred to by Mr. Wiley is possibly the initiative in the final supplanting of direct steam power by electric motors for steel mill operation.

It is perhaps not generally known that if all of the heat energy represented by the coke or fuel consumed in the blast furnaces could be utilized, sufficient mechanical power could be had from it to manufacture the iron produced by such furnaces into merchant shapes. At the present time certain mills are recovering part of the waste fuel from their blast furnaces, which is given off from the furnaces as a very low grade gas, by burning it under steam boilers, using the steam generated for the operation of their electric generators, blowing engines, rolling mill engines, etc. Even with the low economy of the steam engine there is one mill with which we are acquainted which does nearly its entire manufacturing process with power so obtained.

With the advent of the modern large-sized gas engine and the application of large electric motors for roll driving a still more rapid development of electric power in connection with roll mill work may, we believe, reasonably be expected within the next few years. With the increased economy of the gas engine over its steam predecessor the waste blast furnace gases will be able to furnish all the electric power required for the carrying out of the operations incidental to the manufacture of the finished iron and steel product through the use of electric motors. C. S. Cook

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A New Single-Phase Railway

The Spokane and Inland Railway, described by Mr. Ingersoll in this issue of the Journal, is fortunate in being unhampered in the selection of apparatus and methods of operation by a large investment already tied up in equipment on hand, and hence a fair comparison of the various methods proposed could be made without the necessity of taking into account any policies that had been pursued in the past. The company was at liberty to choose the system that was in every way most desirable. This road is one of the first, of a size to compare with steam roads, to be initially operated entirely by electric power. It is not only of steam road size, but it covers exactly the same field. It proposes to carry mail and express and to go into light and heavy freight business, as well as high-speed passenger service. It covers a territory hitherto unoccupied and one that is rapidly developing. It makes direct connection at its terminals with the great transcontinental roads of the Northwest.

The officials of the company from the very first seemed to favor electric rather than steam operation, and also a complete electric system rather than the use of a mixed service. As to the method of electrical operation they apparently decided the case on its merits after a consideration of the different methods proposed. The preliminary estimate given in Mr.Ingersoll's article shows in a very striking way that the single-phase system, even at this early date, can make a remarkably good showing on a financial basis, when compared with the standard long-distance direct-current system. In this case a saving in initial investment, by the use of the single-phase system, is given of about three-quarters of a million dollars. As there is no question but that the expense for attendance is much less for a single-phase system, it follows that the sum of the fixed and operating charges per year must represent quite a marked reduction over those for the corresponding direct-current system.

In addition to the financial aspect of the proposition there are a number of engineering details of interest.

All of the equipment is arranged for multiple-unit operation. Locomotives are used for heavy freight service as in steam practice, with the additional advantage that any number of locomotives can be coupled together and operated by one man, thus doing away with the dangerous "double headers" commonly used for heavy work on steam roads. For light freight and passenger service the multiple-unit system makes it possible to give more frequent service, as any number of cars can be run in one train.

The fact that the power companies of that region generate only 60 cycle power might seem at first sight to be rather unfortunate, but the manner of working out the change to the lower frequency is very neat. The transformation from 60 cycle power to the 25 cycle current for use in the single-phase motors is made by frequency changing sets. Advantage is taken of the change to add to each set a 500 volt direct-current machine. These are mounted on the same bases and shafts with the frequency changers, and are electrically connected to a large storage battery. In operation the direct-current machines act as generators or motors depending on conditions of the circuit. Operating in this way there is quite an interesting set of changes of energy from water power at the generating station to motive power on the cars and locomotives. Starting with power delivered by the turbines, electrical energy is generated in the form of 60 cycle, 4000 volt, three-phase current. This is delivered to the railway company and used in the frequency changers where it is converted into mechanical energy which runs the single-phase 2 200 volt, 25 cycle generators. The power delivered by these generators is then stepped up to 45 000 volts for transmission to the transformer substations, where it is stepped down to the trolley voltage of 6 600 volts. When the load on the railway circuit is small the batteries receive their charge from the 500 volt direct-current machines, which act as generators for furnishing current to the batteries. When the railway load is large the battery furnishes current to the direct-current machines, which act as motors and furnish mechanical energy to assist in driving the single-phase generators. The average load is not carried by the battery, as it is concerned simply with the variations and serves to maintain a uniform load on the generating system. Thus the balancing effect of the storage battery is obtained and, notwithstanding the number of transformations, the operation of the plant under normal conditions is entirely automatic.

One argument against the use of the single-phase system has been the storage batteries could not be used. But the arrangement adopted by the Spokane and Inland furnishes a method of operation by which the storage battery takes care of violent fluctuations in the railway load, helps out on the peak load and is of great value under emergency conditions, thus giving a flexibility quite comparable to that obtained in direct-current systems.

A. H. McIntire

Performance of Apparatus Under Abnormal Conditions

The term "standard" is applied to apparatus which is usually made in quantity and conforms to certain common or normal conditions with respect to voltage, frequency, speed and the like. Standard apparatus has a certain definite performance for which it is designed to operate under normal conditions. Individual pieces of apparatus may vary slightly one way or the other from the average or normal performance.

It happens quite frequently in the selection of apparatus that the conditions to be met differ from the average or ordinary conditions, so that if standard apparatus is selected it will be used under conditions differing from those for which it was designed. Motors, for example, are called upon to operate at different speeds, or at different outputs, or at different voltages from those for which they were intended. The question then presented to the commercial engineer is to determine whether standard apparatus is suitable: first, whether it will perform the required service, and second, whether it will do this safely and satisfactorily. Often the ingenious and resourceful engineer will be able to suggest some modifications in the conditions which will bring them within the range which standard apparatus is qualified to meet.

Hence, the importance of knowing what a given motor or other piece of apparatus will do under abnormal conditions. This, to be definite, may require specific knowledge with regard to the particular motor, for the reason that the range of variation permissible with a motor of one size or for a certain voltage is usually different from those of motors of other sizes or for other voltages. On the other hand, there are certain general relations between the different characteristics of apparatus, the understanding of which is usually helpful. For instance, if one knows the effect of a decrease in the speed of a generator upon its field current he will be able to form a fair idea of the difficulties which may be encountered if a particular machine is to maintain its normal voltage at a speed which is considerably below normal. If one knows the effect of a change in voltage upon the field current, upon the commutation and upon the heating of various elements he can predict the probable effects which may be expected from a change in the voltage of a particular machine.

It is profitable to study the effect which a change in one element makes upon others. Such a study was made with regard to the induction motor in the last issue of the JOURNAL. The effects of over-voltage, under-voltage, lower frequency, higher frequency and a simultaneous change both in frequency and in voltage upon a particular induction motor are considered. This method of treatment and the general principles underlying the changes produced by varying certain elements give the article far more importance than do the particular figures with regard to a specific motor.

Further generalization is useful. With respect to over-voltage, for example, an increase of voltage is, in general, equivalent to increasing the capacity of the motor. An increase of 10 per cent. in the voltage increases the starting torque, the maximum torque and the output at a given slip by approximately 20 per cent. In other words, the capacity of a motor varies as the square of the voltage.

A 10 hp motor at 200 volts becomes a 12 hp motor at 220 volts, insofar as its capacity is concerned. Its losses, however, are considerably greater, so that its temperature would be increased. Its efficiency and power factor will be lower. The suitability of the motor for continuous operation at a higher voltage and increased output depends, therefore, not upon its capacity to carry load, but upon other features which have to do with safety and economy.

If the motor be run at the higher voltage, but with its normal output (in this case 10 hp), then the motor has capacity for 12 hp and is carrying only 80 per cent. load. Several characteristics of a motor, such as slip, maximum torque and starting torque would approximate the ordinary figures for a motor of this size running at 80 per cent. of its normal load.

Conversely, if a motor be run at 10 per cent. below normal voltage, then the capacity is decreased about 20 per cent. A 10 hp motor would have the characteristics of an 8 hp motor in starting and in maximum torque and in output at normal slip. If, at the lower voltage, the motor be given its full load of 10 hp, its characteristics will be quite similar to those of a motor which is carrying 25 per cent. overload.

The habit of thus establishing in one's mind the various fundamental relations between the different elements in the operation of a motor or other apparatus, by which one can foresee the effect which a change in one element will produce upon other elements, will prove very useful to most engineers who have to do with either the selection or the operation of apparatus. It is further desirable, of course, to know the approximate limits of safety and economy, in order that these elements may not be exceeded.

Chas. F. Scott

Reverse Current Relays

Reverse current relays for alternating-current circuits are designed to operate when the direction of the flow of energy is reversed from that required for normal operation. In actual practice they are principally used to guard against trouble arising from a reversal under the following conditions:

1—Improper adjustment or loss of field on one of several alternating-current generators operating in multiple, when the machine would act as a partial short-circuit on the bus-bars.

2—Cutting off of power from a transmission line feeding rotary converters or synchronous motor-generator sets operating in multiple with storage batteries or other generators, in which case the rotary converter or synchronous motor would tend to run inverted and supply power to the transmission line.

3—A short-circuit or ground on one of several lines operating in multiple to supply power from a generating station to a sub-station. While the damaged line will be cut off from the generating station by the action of the over-load circuit-breaker at that point the other lines in multiple with it would continue to supply power to the damaged line through the sub-station.

In the first case, which is of rare occurrence, the station operator can usually adjust or cut off the generator before any damage is done and without any necessity of shutting down the plant.

In the second case it is customary to use a polarized relay in the direct-current circuit to trip the circuit-breaker connecting the machine to the direct-current bus-bars and at the same time to open the circuit-breaker in the alternating-current circuit. This type of relay works in a very satisfactory manner.

In the third condition the reverse current relays are located in the receiving station and operated from transformers in the circuit between the incoming lines and the bus-bars. In case of trouble on one line the overload circuit-breaker at the generating station would open, but the remaining lines would feed into the disabled one through the sub-station bus-bars. Under these conditions the flow of energy in that line would be *from* the bus-bar instead of to it and this reversal of direction would cause the relay to trip the circuit-breaker connecting that line to the bus-bars.

A short-circuit on one line often causes such heavy currents to flow that the line drop becomes excessive and the sub-station voltage so small and the power-factor so low that the earliest types of reverse current relays would fail to operate and in many plants they have been discarded as useless.

The relay described in this issue of the JOURNAL by Messrs. MacGahan and Baker is intended to obviate the troubles inherent in the older types Judging from the curves shown in the article this relay should prove very satisfactory in service and an extremely useful piece of apparatus.

S. Q. HAYES

Articles on Organizations

The article on The Union Switch and Signal Company in this issue follows a similar article with regard to Westinghouse, Church, Kerr & Company in the last issue of the JOURNAL. These articles which trace the development and exhibit the scope and character of the work of these organizations are of especial value to those who are more or less intimately connected with these particular companies, and they will also be found of great interest to those whose duties, present or prospective, may bring them directly or indirectly in contact with organizations which are typical of modern engineering methods.

The importance of a just appreciation of the efforts of others with whom one may have to do was brought out in the introductory remarks to the present paper, as follows:

"*The man who sits and works within a narrow circle, who sees but little beyond that circle, acquires a sort of provincial conceit and complacency that is really dangerous.*

"*He gets to thinking the work he is doing is very important, and that the work of other people is of comparatively little importance.*

"*Any man who is responsible for the administration of a large organization runs against this all the time.*

"*It is one of the serious matters that an executive officer has to encounter—the narrow-mindedness of ignorance—and for that reason alone it is of great importance that men in each department should have at least some reasonable conception of the kind of work being done in other departments.*"

THE SPOKANE AND INLAND SINGLE-PHASE RAILWAY

J. B. INGERSOLL

Assistant General Manager and Chief Engineer of the Spokane and Inland Railway

THE Spokane and Inland Railway furnishes the first example, large or small, of the use of single-phase railway equipment in the entire Pacific Northwest, and is the second one to begin operation on the Pacific coast, its immediate predecessor being the Vallejo, Benicia and Napa Valley Railway Company, of Southern California.

Beginning at Spokane, Wash., where immediate contact is made with several transcontinental lines—the Great Northern, the Northern Pacific and the Union Pacific systems—the Spokane and Inland extends in a general southerly direction for a distance of seventy-six miles to the city of Colfax, Wash., which in that direction constitutes the present terminus; at Spring Valley junction, 39 miles from Spokane, a branch line runs to Palouse, Washington, this branch being about 40 miles in length, making the total length of line at present, 116 miles, or 125 miles including sidings. Extensions to one or possibly both of these branches of the "Y" thus formed will no doubt be made in the very near future.

FALLS OF THE SPOKANE RIVER, THE SOURCE OF POWER FOR THE SPOKANE & INLAND

The entire field traversed by this electric line is one of great fertility. It is the Palouse country, known especially in the grain market as a great wheat producer, and furthermore destined to develop as a timber producer, since the Washington, Idaho & Montana Railway has built east from Palouse, reaching into one of the largest bodies of white pine timber now standing, and a four band sawmill has been erected at Potlatch, Idaho, eleven miles up the Washington, Idaho & Montana Railway from Palouse. This mill will have an immense capacity, cutting in the neighborhood of a million feet of timber each day, which will mean thirty or more cars of lumber distributed daily to the various transportation companies, the Spokane and Inland handling its share of the tonnage. This wheat, lumber, etc., will make heavy freight. A firm official determination existed on the part of the Spokane and Inland Company from the very beginning to handle this freight electrically, and, according to steam road practice, to employ heavy motive power.

By reason of unfavorable weather conditions, such as heavy snowfall and also because of the extensive trackage, yards, etc., it was not feasible to consider a third rail system, so direct-current considerations were at once reduced to the necessary use of a double No. 0000 overhead trolley paralleled by copper, varying in size from 500 000 to 750 000 circular mils throughout almost the entire system. A lengthy computation was prepared showing the relative advantages of single-phase and direct-current operation. The report submitted to the officials of the road was summarized in about the following manner, the parallel columns showing the relative costs involved by the three-phase, 60-cycle rotary converter system and the single-phase, 25-cycle system. These figures apply

BRIDGE CONSTRUCTION ON THE SPOKANE & INLAND to a total mileage of 146 of main line, which in actual construction has since been reduced temporarily by thirty miles:

	Direct Current.	Alternating Current.
Electrical equipment of rolling stock.. ..	$259 600	$286 250
Trolley line (two No. 0000 conductors) ..	343 100	
Trolley line (catenary construction)		306 600
Transmission	122 640	140 000
Feeders	474 600	19 800
Bonding	40 150	40 150
Rotary sub-stations..	338 548	
Transformer sub-stations..		156 988
Frequency changing stations..		106 400
	$1 578 638	$1 056 188

Saving of Alternating over Direct Current $522 450

Due to changes made after the contract for the equipment was closed, it is now considered that the saving effected was in the immediate neighborhood of $800 000, representing, at five per cent., an interest of $40 000 per annum, and also a very large percentage of the total cost of the system using direct-current apparatus.

POWER

Practically all of the electric power systems on the Pacific coast are equipped with 60-cycle apparatus. In this respect conditions at Spokane did not differ from the majority of cases and, as it was decided to buy power from an existing power system, the use of frequency changers was the only expedient to follow.

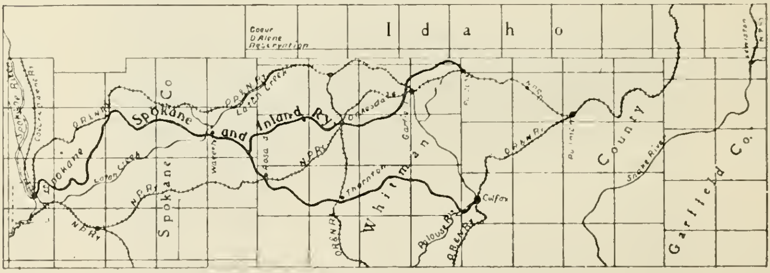
These were selected in units of 1 000 kw, four sets being required, each set consisting of three separate machines, all mounted on the same base plate, each being of the two bearing, self-contained type with flange coupling between adjacent rotating elements. The 1 000 kw, 25-cycle revolving field, single-phase 2 200 volt generator is coupled at one end to a 1 000 hp, 3-phase, 60-cycle, 4 000 volt induction motor operating at full-load speed of 500 r. p. m.; at the other end it is coupled to a 750 hp, shunt-wound 550 volt direct-current machine, which is designed to act as a load balancer for the induction motor, keeping the input to that machine as nearly constant as possible, and as far as the 60-cycle system is concerned, minimizing the peak loads. The direct-current machine will charge and discharge a storage battery through a booster system, the booster field compensator being actuated from the secondaries of series transformers, placed in the 4 000 volt circuit to each induction motor. This is the first system of the sort to be applied to alternating-current railroading and offers a new field to the storage battery.

The alternating-current power is taken direct from the 4 000 volt, 60-cycle generator bus-bars, transmitted two miles to the frequency changing station, and sent out at a potential of 45 000 volts, 25-cycle, single-phase, to the various transformer stations along the right of way.

The frequency changing station is a brick, concrete and steel structure of imposing design and together with the 60-cycle power plant, is located inside the city limits of Spokane.

SWITCHBOARD

The switchboard in the frequency changing station consists of 24 panels. All oil switches are mounted separate from the switchboard, each being operated through a system of connecting rods and bell cranks.



ROUTE OF THE SPOKANE & INLAND RAILWAY

Graphic recording instruments are placed in the incoming 4 000 volt, 60-cycle circuits and also in the 25-cycle end of the equipment, these furnishing a continuous station log of the power received and the power delivered.

TRANSFORMER STATIONS

For the 116 miles of line, eleven transformer stations are used, consequently the average distance between them is approximately 10 miles. The buildings will be of concrete and brick construction, and will each house the following equipment:

2—Low equivalent 45 000 volt lightning arresters.
1—Automatic 45 000 volt oil circuit breaker.

2—375 kw, 45 000-6 600 volt oil insulated self-cooled transformers.

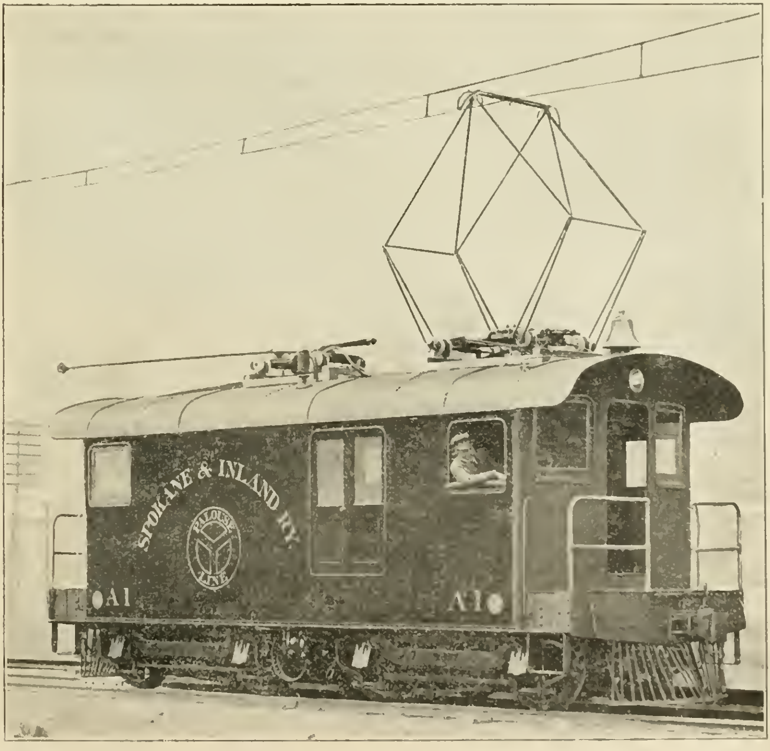
2—Automatic 6 600 volt oil circuit breakers.

1—6 600 volt lightning arrester.

1—Full complement of disconnecting switches for 60 000 and 6 600 volts.

TRANSMISSION LINE

The 45 000 volt single-phase transmission line parallels the track but is separate from the trolley structure. No. 2 hard drawn copper wire is used and is supported on a single cross arm, the wires being spaced 48 inches apart. The insulators are of the three part type, glazed together and tested at 120 000 volts. Metal pins are used of the type made by the Locke Insulator Company. The poles are of Idaho cedar with a minimum top diameter of eight



SPOKANE & INLAND SINGLE-PHASE LOCOMOTIVE inches, forty feet long and set at an average distance of 100 feet apart on tangents and 50 feet on curves.

TROLLEY LINE

The trolley construction is of standard single catenary, single arm type, for a working potential of 6 600 volts. Especial care has been exercised in erecting this line and material has been used unsparingly, the result being that an excellent example of high class work is here afforded. It has been put up to stay. The poles are of well selected Idaho cedar, 40 feet long with a minimum top diameter of eight inches and are set six feet in the ground. Many holes had to be blasted out of the solid rock. A large percentage of the poles are guyed securely and especially so on curves. The trolley wire is 22 feet above the head of the rail.

LOCOMOTIVES

Six locomotives are being supplied, each weighing approximately 50 tons, of the double truck type, equipped with four 150 hp, single-phase railway motors, having a normal voltage of 225 volts. The dimensions of the locomotives are as follows:

Height from head of rail to top of cab, 11 feet, 9 inches.
Width over all, 9 feet, 6 inches.
Length over bumpers, 32 feet, 6 inches.
Rigid wheel base, 7 feet, 4 inches.
Wheels, 38 inches diameter.
Distance between truck centers, 13 feet, 9 inches.

All locomotives are double end, fitted with straight and automatic air brakes, and electro-pneumatic multiple-unit alternating-current and direct-current control, and have duplicate motor-driven air compressors.

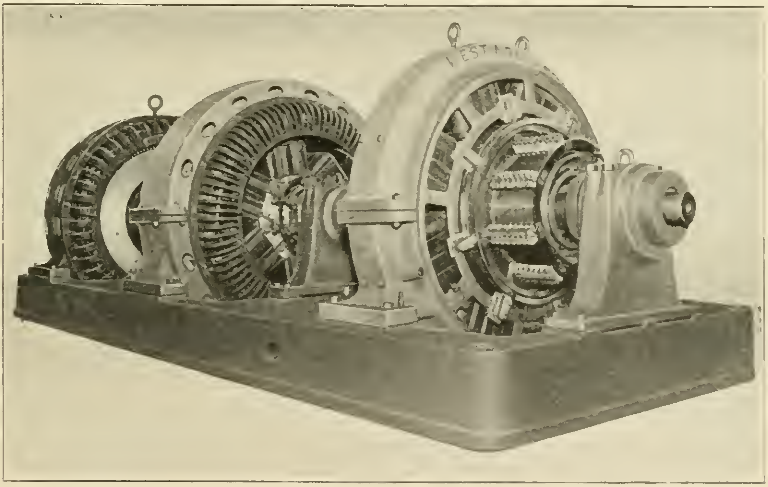
Most of the control and brake equipment will be inside of the cab in a very accessible position, facilitating ready inspection of parts and quick repairs.

Two auto-transformers of the oil insulated self-cooling type are supplied for each locomotive, having a combined capacity sufficient to supply the motors with power under heavy overload conditions. These are also placed inside the cab.

Each locomotive is intended to haul seven 45-ton cars on a level track at 30 miles per hour and ten such cars on a level at 25 miles per hour. When coupled in tandem, the weights back of the drawbars may be doubled. It is proposed to use double-headers in regular service and to do practically all of the heavy freight work at night, thereby keeping the load-factor of the system as high as possible.

PASSENGER CAR EQUIPMENT

Standard passenger trains consist of three coaches, two with motors and one without motors. The two motor cars are run in front, leaving the third car as a trailer. The electrical equipment for each motor car consists of four 100 hp, single-phase motors, complete with both alternating-current and direct-current multiple-unit pneumatic control and one auto-transformer of the oil insulated self-cooling type. The trolleys for alternating-current service are of the pneumatically operated pantagraph type. Wheel trolleys with bases insulated for 6 600 volts are also supplied, an oil type emergency switch being used for interconnection between the trolleys in case of failure of one or the other. Each motor car with load weighs complete approximately 42 tons, the trailer 31 tons, making a three car train weigh approximately 115 tons total. The car wheels are 36 inches in diameter, which with a gear ratio of 20:63 gives a speed of 45 miles per hour, on a level track.



SPOKANE & INLAND MOTOR-GENERATOR SET
1—1 000 hp, 4 000 volt, 3-phase, 60 cycle, 500 r. p. m. induction motor
1—1 000 kw, 2 200 volt, single-phase, 25 cycle, rotating field generator.
1—750 hp, 550 volt, direct-current shunt wound machine, which acts alternately as motor or generator, depending on the load

A two car train made up of a motor car and trailer, of a total weight with load of 73 tons, has a maximum speed of 50 miles per hour on the level and a schedule speed of 36 miles per hour on a four mile run. All equipments, including the locomotives, are designed to work on standard 600 volt direct-current trolley lines when desired, as all trains entering the terminal station in Spokane use direct-current.

At present 15 quadruple equipments of 100 hp motors have been ordered for passenger trains. Six motor cars will be the combination passenger and baggage type, 59 feet in length, all single end control. Five cars will be of the straight passenger type, 56 feet, 6 inches long, all single end control. One motor car of the straight passenger class will be double end control and will be used for service. There will also be three 58 foot observation cars without motors. Car bodies and trucks for the remaining three complete motor equipments have not yet been ordered.

FREIGHT MOTOR CARS

For light freight and express service, there are six quadruple, 100 hp equipments, these being the same as those used on passenger service, except that the gear ratio is lower and all are of the double end type in both electric control and brake equipment, both straight and automatic brakes being used. The air compressors are in duplicate. The car bodies are of the box type 50 feet long over the bumpers. Besides having a large freight carrying capacity, they will be used as light weight locomotives and will be capable of hauling two 45 ton cars on the level at 45 miles per hour. Heavier trains can be handled if desired on shorter runs without overheating the equipment. These lighter locomotives may be run tandem or multiple, making them valuable auxiliaries to the heavier locomotives during periods of congested freight traffic.

ELECTRO-MOTIVE-FORCES INDUCED IN PARALLEL CIRCUITS*

A. W. COPLEY

A TABLE was given in the June issue of the JOURNAL in an article on "The Calculation of the Electro-Motive-Force Induced in Transmission Circuits," from which the voltages induced in any circuit by an alternating-current in a parallel circuit could be obtained. The application of the general method of calculation is best illustrated by a few simple concrete cases.

The part of the table which will be used (from pages 337 and 338 of the June issue) is as follows:

Common logarithm to be employed in order to find the e.m.f. induced in various secondary circuits by current in circuit *AB:*

(3) e.m.f. in C-D; $\log \frac{bc}{ad}$

(6) e.m.f. in A-D; $\log \frac{be}{0.78\ rd}$

(9) e.m.f. in A-B; $2 \log \frac{e}{0.78\ r}$

Constants for one ampere and one mile length:

Frequency, 25 cycles; Constant, 0.116

Frequency, 60 cycles; Constant, 0.279

Consider four wires, *A*, *B*, *C*, and *D*, parallel to each other and arranged as in Fig. 1. $a = 8$ in. $= d$; $b = 17.9$ in. $= c$; $e = 16$ in. $= f$; $r = 0.1021$ in. The length of lines parallel to each other is taken as one mile and all wires are assumed to be No. 4 B. & S. gauge.

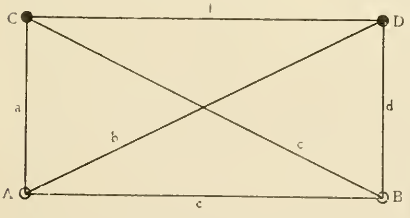


FIG. 1

Case I. Current of 100 amperes at 25 cycles in circuit *AB*. To find the induced voltage in circuit *CD*. Use (3) from the table given; then,

$$\log \frac{bc}{ad} = \log \frac{320}{64} = \log 5 = 0.699.$$

Multiplying this by 0.116 the constant for 25 cycles and one mile length of parallel circuit, and by 100, the current in *AB*, gives the induced voltage in *CD* as, $100 \times 0.116 \times 0.699 = 8.1$ volts. This is independent of the size of the wires.

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*This is the fourth in a series of articles dealing with the characteristics of transmission circuits. The earlier articles appeared in the December, February and June issues.

Case II. Current of 100 amperes at 25 cycles in *AB*. To find the voltage induced in itself. Apply (9) from the table and multiply by the same constant as in Case I. $100 \times 0.116 \times 2 \log \frac{e}{0.78\,r} = 23.2 \log \frac{16}{0.0796} = 53.4$ volts.

Case III. Current of 100 amperes at 25 cycles in *AB*. To find the induced voltage in AD. From (6) we have $\log \frac{be}{0.78\,rd}$ and using the constant 0.116 the induced voltage is $100 \times 0.116 \times \log \frac{17.0 \times 16}{0.78 \times 0.1021 \times 8} = 30.7$ volts.

Case IV. The three foregoing cases have dealt with the effect of only one current. Suppose, however, that not only *AB* is carrying current but that a second circuit *CD* carries a current of the same frequency and phase. The circuit *CD* will then have a voltage induced in it by the current in *AB* and also by the current in itself.

Assume that AB carries a current of 100 amperes at 25 cycles, and *CD* carries a current of 50 amperes at 25 cycles. To find the induced voltages in CD:

(a) When *A* and *C* are like sides of the two circuits.

(b) When *A* and *D* are like sides of the two circuits.

The induced voltage in *CD* due to current in *AB* is from Case I, 8.1 volts. The induced voltage is *CD* due to current in itself is $50 \times 0.116 \times 2 \log \frac{16}{0.0796} = 26.7$ volts. These two voltages are in phase with each other and the total effect in *CD* is the sum of $8.1 + 26.7 = 34.8$ volts.

(b) The same voltages will be induced in *CD* with the current reversed in either circuit but the two voltages will be opposing each other and the total effect will be, $26.7 - 8.1 = 18.6$ volts.

Case V. If the four wires make up one circuit, each side of the circuit being composed of two wires in parallel, the induced voltage in the circuit can be calculated by three possible arrangements of the wires, assuming 100 amperes per wire as follows:

(a) *A* and *C* in parallel; and *B* and *D* in parallel.

To find the induced voltage in the circuit. As the two circuits are symmetrical the induced voltage in *AB* will be equal to that in *CD* and as they are in parallel this will be the induced voltage in the whole circuit.

The induced voltage in *AB* due to current in *CD* is $100 \times 0.116 \times \log \frac{bc}{ad} = 8.1$.

The voltage in *AB* due to current in itself is by Case II, 53.4

volts. The total induced voltage $= 53.4 + 8.1 = 61.5$ volts.

(b) *A* and *B* in parallel; and *C* and *D* in parallel.

The induced voltage in *AC* due to current in *BD* is $100 \times 0.116 \times \log \frac{bc}{ef} = 1.1$ volts. The induced voltage in *AC* due to current in itself is $100 \times 0.116 \times 2 \log \frac{a}{0.78r} = 46.4$ volts. The total induced voltage is $1.1 + 46.4 = 47.5$ volts.

(c) *A* and *D* in parallel, and *B* and *C* in parallel.

This is the same as either (a) or (b) if one of their pairs be reversed, and the induced voltage will be the difference between the two voltages in each instead of the sum. Subtracting the two voltages in (a), $= 53.4 — 8.1 = 45.3$ volts.

Likewise for (b), $46.4 — 1.1 = 45.3$ volts.

The voltages above calculated are in most cases not what would be actually read on a voltmeter because of the voltage required in the circuits to overcome the resistance of the wires.

This voltage is in phase with the current, while the induced voltage is in quadrature with the current. The total voltage measured by the voltmeter would be the vector sum of the two component voltages or the square root of the sum of the squares of the induced voltage and the voltage drop due to the resistance.

In Case I there is no current in *CD* and therefore in that case the induced voltage is the only one in the circuit. But in Case II the resistance drop in *AB* due to 100 amperes flowing through two miles of No. 4 wire must be added to the 53.4 volts to get the total voltage used in the line. This resistance drop is 266 volts. The total voltage used in circuit *AB* is therefore $\sqrt{266^2 + 53.4^2} = 271$ volts. In Case III the resistance drop in *A* only must be added to the induced voltage in *AD* of 30.7 volts to obtain the total voltage as measured by a voltmeter. This amounts to $\sqrt{133^2 + 30.7^2} = 135.6$ volts.

To show the effect on the induced voltage of changing the positions of the wires the voltage induced in the secondary circuits by currents in the primary in Fig. 2 have been calculated using the method illustrated above. The primary circuit may be a power circuit of any kind and the secondary either a power circuit or a circuit transmitting very small current such as telegraph or telephone currents.

The voltage induced in the secondary circuits (Fig. 2) are those induced by a current of **100** amperes in the primary.

VOLTAGE INDUCED IN SECONDARY

Group					25 cyles	60 cyles
	X	X				
No. 1.					3.5 volts	8.4 volts
	O	O				
	X	O				
No. 2.					0.0 volts	0.0 volts
	O	X				
No. 3.	X	X	O	O	1.35 volts	3.5 volts
No. 4.	X	O	O	X	7.0 volts	16.8 volts
No. 5.	O	X	X	O	7.0 volts	16.8 volts
No. 6.	X	O	X	O	5.5 volts	13.3 volts
No. 7.	X	O	X	O	0.0 volts	0.0 volts

FIG. 2

X=Wires carrying primary current.
O=Wires in which secondary voltage is induced.

In the first two groups the four wires are at the corners of a square. In the next four figures the wires are presumed to be on one cross-arm, on which the pins are equally spaced. In the last figure the distance from each outside wire to the adjacent wire is 0.707 of the distance between the two current-carrying wires.

OPERATION OF GAS-DRIVEN ELECTRIC POWER SYSTEMS

AS EXEMPLIFIED IN THE WARREN & JAMESTOWN SINGLE-PHASE RAILWAY SYSTEM*

J. R. BIBBINS

TO obtain a correct idea of the conditions at Warren† it is sufficient to say here that a gas engine plant of 1 000 hp capacity, in two units, is operating, without steam reserve, an entire railway system totaling 42 miles of road, half city and half interurban, the latter traversing a difficult country, with but two to four cars in service, all of unusual size (35 tons), high speed (50 miles per hr.) and powered 200 hp per car. Upon this plant, which regularly operates 80-90 per cent. of the time, the entire traction service of an important community depends.

With a definite operating schedule the load demands may, in a sense, be anticipated; for instance, when starting on the even and half hour from termini. But, practically, it is impossible to anticipate their extent, with the result that maximum generating capacity must be kept continually in service, although at one time the load may fall to practically nothing and at the next instant rise to the limit of the plant capacity.

LOAD DIAGRAMS

It is difficult to convey on paper an adequate impression of the severity of a load like this. Some idea may be obtained from the accompanying load diagrams, Fig. 1, which show the actual movement of the mixing valves on one of the gas engines to accommodate the changes in impressed load. Even these do not represent the very worst conditions, for it frequently occurrs that cars become "bunched," particularly during the summer months when holiday traffic is usually heavy, taxing the entire system to its utmost.

These diagrams were taken by moving a strip of metallic coated paper at uniform speed in contact with a pencil attached to the valve motion. This motion is rectilinear and proportional to the amount of gaseous mixture admitted to the cylinders. Consequently it is proportional to the effective load, and the ordinates record the fluctuations of power which must be met by the generating unit. Incidentally, it shows the sensitiveness which characterizes the method of governing used.

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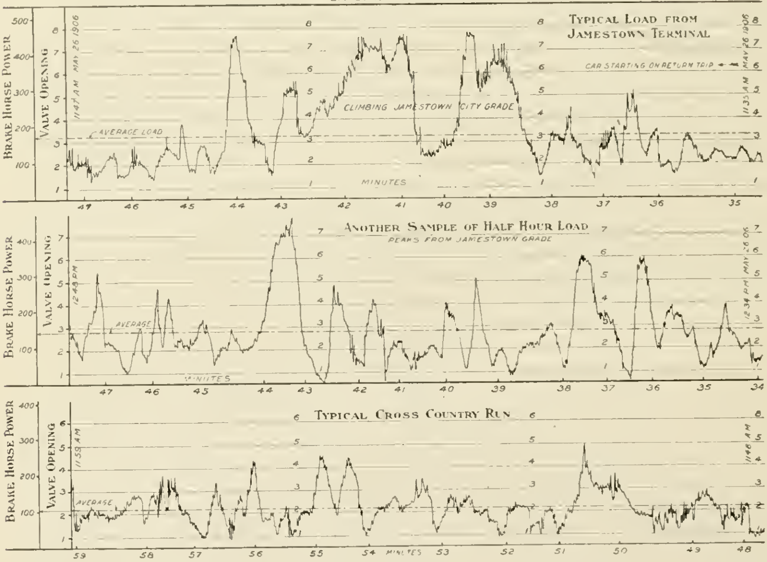
* From a paper presented before the Engineers' Society of Western Pennsylvania, June 5, 1906.

† See article on "Some Features of the Warren Gas Power Plant," in *The Electric Journal,* Vol. III., No. 4.

These three samples shown were taken from a long strip of record covering a period of one hour, each strip corresponding to an interval of about ten minutes, during different parts of the hour's run. The upper strip records the load occurring regularly through the day at half after the hour. At this time one interurban car leaves Jamestown on its return trip, and the heavy load at 11:30-11:42 results from the long grade leading out of the city. About this same time another car is running across country, as shown by the train sheet, Fig. 2, while a third car is just pulling into the Warren terminal. The second strip records a similar load one hour later and shows practically the same characteristics. On the third strip is recorded the comparatively easy load which results from two cars out on the line.



RECORDING LOAD CHARTS

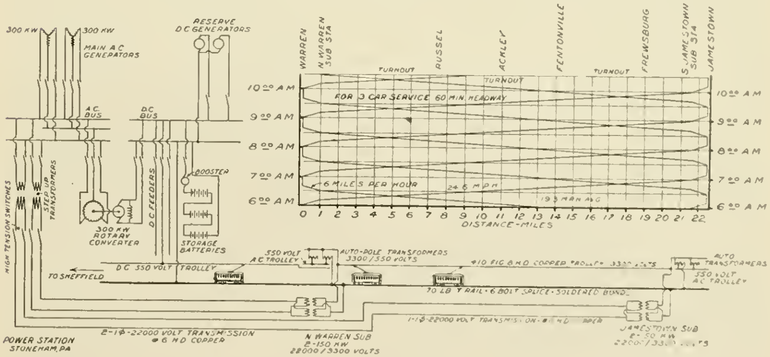
SHOWING ACTUAL OPENING OF MIXING VALVES ON GAS ENGINES AT MAIN POWER STATION

SEE SCALE AT LEFT

FIG. I

The scale for these records, affixed at the left-hand margin, was constructed by making a few observations at the end of the run at several different points of valve opening corresponding to various loads coming within the range of fluctuations. This method was found to be quite accurate, checking closely with observations made at intervals during the time the record was being taken.

Observe now that within these ten-minute intervals there result from 15 to 18 peaks with load varying from less than 100 hp up to the rated capacity of the engines. The suddenness with which these loads increase and decrease is shown at 11:44, 12:36, and 12:44, respectively. Previous to May, 1906, when a 90-minute schedule was in use, cars started simultaneously from the two termini which still further accentuated the severity of the load fluctuations at the plant. At the present time express cars on their regular daily runs carry loads varying from three tons average to ten or fifteen tons; it is nothing unusual for these cars to haul ten to fifteen barrels of oil, or a load of dressed oak timber, which pulls heavily on the steep grades. It is unnecessary to emphasize the fact that this kind of load is the worst that a reciprocating engine can be called upon to sustain.



APPROXIMATE TRAIN SHEET
POWER STATION ARRANGEMENT AND DISTRIBUTION SYSTEM
WARREN AND JAMESTOWN ST. RY. CO.
WARREN PA.

FIG. 2

The fact that the Warren plant is capable of meeting these fluctuations without rapid deterioration should furnish a convincing proof of the stability of the modern gas engine.

Another point of important bearing upon the success of a power plant is the character of labor available. Owing to the distance of the power plant from the city and its complete isolation after running hours, it is difficult to retain skilled operatives. Thus at the present time, although one such man is retained as superintendent, the remaining attendants were quite inexperienced, most of them having come up from the ranks in street railway service or from outside employment. During the past six months these men have acquired sufficient knowledge and skill to enable one of their number, a comparatively young man, to take entire charge during the night run.

POINTS DEVELOPED FROM OPERATION

A general survey of the operation of the Warren gas engine plant up to the present time brings to mind the following points that would now seem to have been established:

1—Ability to handle variable loads.

2—Regulation suitable for alternating-current parallel operation.

3—Effect of misfires negligible.

4—Sufficient reliability for regular daily service.

5—Deterioration from wear quite normal.

6—General character of labor required not above the ordinary. nary.

7—Oil and water consumption low. Automatic systems desirable.

8—Automatic starting system quite sufficient for any emergency.

PARALLEL OPERATION

Not the least impressive feature of the Warren plant is the ease with which the gas engine units are operated in electrical parallel. They are synchronized by the ordinary lamp method and on opening the throttle. The author has observed the entire operation of unloading, synchronizing and loading again accomplished within a period of twenty-five seconds without the least evidences of surging at the instant of closing of the switches. When synchronized, loads are distributed in the manner usual with steam machinery, the governor adjustment being accomplished by an adjustable lever arm attached to the regulator by a spring cushioned oil dash-pot. In practice the governors are so adjusted as to give practically the same port opening at the mixing valves, which insures a fairly even distribution of load at the switchboard. During the excessive load fluctuations reproduced in Fig. 1 the units showed no tendency to hunt; in fact, operated with the greatest stability on the heavier loads.

EFFECT OF MISFIRES

The effect of misfires on parallel operation has been subject to much conjecture and it is of interest to know that, although misfires occur now and then, as they are bound to do, in not a single instance have electrical troubles resulted during normal operation. With one cylinder entirely isolated by a defective igniter it is, of course, probable that some surging would result, but the misfires that do occur are so seldom continued and are so easily remedied that no trouble whatever is apprehended from this source.

GENERAL RELIABILITY

As to the general reliability, the facts presented are self-explanatory. After six weeks' run the unit first started was shut down to examine its internal condition. Every part was found to be in good working order, without evidence of excessive wear or stress; in fact, the cylinders still retained their original toolmarks. Since then the engines have been in such constant service that no opportunity has presented itself for further inspection, and all detail parts are operating in their original condition with the exception of the igniters. These are periodically re-

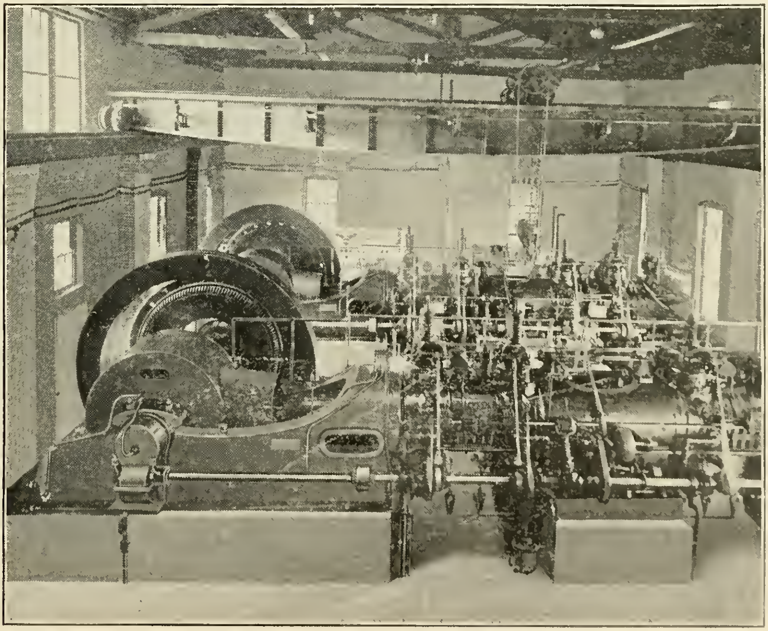


FIG. 3—GENERAL VIEW OF INTERIOR OF WARREN & JAMESTOWN POWER PLANT, SHOWING GAS ENGINES DIRECT-CONNECTED TO GENERATORS

moved for cleaning during the early morning shut-down. It is a significant fact that in spite of the hard service, exhaust, admission, and mixing valves, piston rods, glands, connecting rods, main bearings, and cylinders have operated without mishap and show no evidences of abnormal deterioration after seven months' daily run. Piston rods have done exceptionally well in regard to wear, owing to the efficient packing and method of gland lubrication; both rods have retained their original polish and run quite clean without tendency to gum.

OILING SYSTEM

Undoubtedly no small part of the success in operation is traceable to the oiling system. Realizing that oil is an absolute essential and that oilers are human beings and, therefore, not infallible, the designer has relieved them of the greater part of their responsibility by using a continuous circulating and filtering system. This also results in a great saving of lubricant, which in turn encourages the use of the highest grade oil. Cylinder lubrication is particularly effective owing to the judicious application of lubricant at just the right time. The oil is automatically injected into the cylinder at several points, but only on the induction stroke; not promiscuously, as is almost universally done, resulting in the carbonization of by far the largest proportion. By the end of the compression stroke the oil is thoroughly distributed. Table I gives the oil consumption as charged to the main plant. It is augmented by the fact that more or less oil is drawn out of the system weekly for use in auxiliaries around the plant, this being replaced by fresh oil. Some cylinder oil is also saved from piston-rod glands as all drainage is caught, mixed with old engine oil, and utilized in crank cases of the exciter engines for which no oils are regularly purchased. This accounts in part for the quantity of cylinder oil used, which is somewhat higher than in other en-

TABLE I. OIL CONSUMPTION

For Months ending May 23, 1906

	Cylinder Oil.	Engine Oil.
Price (barrel lots)	32c per gal.	18c per gal.
Quantity used	561 gals.	765 gals.
Quantity used per (operating) day	4.68 gals.	6.38 gals.
Oil per engine hour	0.127 gals.	0.172 gals.
Oil per hp hr.	0.000253 gals.	0.000345 gals.
Cost per engine hr.	4.05c	3.1c
Cost per hp hr.	0.00809c	0.00621c
Total cost		0.0143c per hp hr.

gines of the same design. A gallon per engine per day is sufficient, in most cases, with clean gas.

WATER CONSUMPTION

Water consumption, however, is rather low, due to the fact that the average load on the engine is considerably below rating and peaks are of short duration. Owing to the abundant supply available the jackets are run unusually cool (See Table II.). It is noteworthy that successful circulation is being obtained from the elevated tank without the use of a pressure pump to supply pistons. At Warren the extraordinary purity of the water makes clogging of water ducts improbable and 10 pounds hydrostatic head may therefore be depended upon with entire safety.

STARTING MECHANISM

The automatic compressed air starting mechanism has proven to be one of the most effective details of design and has never failed, providing the proper pressure is maintained in the tanks and the ignition is in good working order. In starting the engines only two valves are manipulated, viz., the compressed air valve and the gas valve, both shown in the foreground in Fig 3, and usually the engine "catches" its ignition in two or three strokes, coming rapidly up to speed within one minute.

OPERATING DATA

In the accompanying tables an attempt has been made to summarize the most important operating data pertaining to the power equipment of the system for a period covering normal operation under different conditions. Previous to December the interurban road was not in complete shape and operating data therefrom would not be representative. The car mile and ton mile has been taken as a basis for all computations, and Table III. gives the fundamental data for arriving at these quantities.

Table II. Water Consumption—Main Engines*

Temperature April 27, 1906.		
Inlet	39°F	Rise
Tail rod, av.	100	60°F
Cylinder jacket, (av.)	106	67
Exhaust valve (av.)	66 & 63	27 & 24
Outlet average	93	54

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* Source—Spring water, no suspended matter.
Storage System—Cistern, auto-raising pump, elevated supply tank.
Pressure at Engines Average—9-10 pounds per square inch.
Quantity used per hour per engine—2824.5 gallons.
Water per brake-hp per hour, full-load—5.65 gallons.

TABLE III. SUMMARY OF OPERATING COST DATA

SYSTEM	A.C. Interurban System Only		A.C. Interurban & D. C. Urban		A.C. Interurban & D. C. Urban	
Month 1905-6	Dec. & Apr.		Jan. Feb. Mch.		May (†)	
Interurban schedule*	1½ hours		1½ hours		1 hour	
Number of cars in all regular service	2 passenger 1 express		2 passenger 1 express		3 passenger 1 express	
Weight of cars	35 tons		35 tons		35 tons	
Headway	90 minutes		90 minutes		60 minutes	
Lay over	50 minutes		50 minutes		20 minutes	
Operating time	17½ hours		17½ hours		18½ hours	
Total number round trips	14		14		20	
Total mileage per car	315		410		440	
Car miles per day, interurban	650		630		880	
Car miles per day, city			2381		2381	
Total car miles	630		3011		3261	
Ton miles per day, interurban	22050		22050		30800	
Ton miles per day, city			27310		27310	
Total ton miles	22050		49360		58110	
Average tonnage per car	35		16.1		17.82	
	Month	Day	Month	Day	Month	Day
Cost fuel gas	$257.10	$ 8.43	$382 90	$12.76	$394 95	$12.74
Wages	296.00	9.79	371.00	12.37	371.00	12.37
Oil	80.00	2.65	80.00	2.63	80.00	2.63
Sundry supplies and repairs	100.00	3.31	100.00	3.29	100.00	3.29
	$733.10	$24.18	$933.90	$31.05	$945.95	$31.03
Total cost per operating hour	$1.38		$1.774		$1.677	
Total cost per (24 hr.) hour	1.01		1.295		1.294	
Total cost per car operating hour	0.645		0.194		0.166	
Total cost per average car mile	3.84c		1.031c		0.95c	
Total cost per average ton mile	0.1096c		0.0629		0.0534	
Gas consumption†† per	Cu. Ft.	Cost	Cu. Ft.	Cost	Cu. Ft.	Cost
Average car per hour	1503	22.5c	532	8.04c	434	6.81c
Average car mile	89.3	1.34	28.3	0.427	26	0.391
Average ton mile	2.55	0.0383	1.72	0.0261	1.46	0.022

	Sheffield.	North Warren.	City.	Total or Avg.
Length of Line (Miles)	11	3	7	
No. Cars in regular operation	2	1	4	7
Headway, Minutes	60	20	15	
Weight of Cars (Avg. Tons)	18	15	10	11.5
Operating hour per Day	17	17	17	17
Car Miles per Day	374	102	1905	2381
Ton Miles per Day	6730	1530	19050	27310

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†May expenses (except gas) averaged on 30 day basis.

*Warren City System.

††Gas from "Bradford sand" Elk County—1 000 B. T. U. per cu. ft. approximate.

Price—15c per million B. T. U.=1c per 66667 B. T. U.

Equivalent cost of coal (13 500 B. T. U. per lb.)—

$1.00 per ton= 3.7c per mill B. T. U.

2.00 per ton= 7.41c per mill B. T. U.

15c per mill=$4.09 per ton coal.. 4.00 per ton=14.82c per mill B. T. U.

In Table III. the total operating costs, on a basis of car and ton mile, are summarized for three definite operating conditions. As the one-hour schedule has been in force only about one month, the costs may not be quite as representative for May as those covering 1½-hour headway. Further, the costs for December and April are, if anything, high for the reason that during April the interurban plant furnished some power to the urban system during some work on the electrical machinery, although the results are considered as applicable to the interurban system only. In order to render the results from May more comparable with those of shorter months the costs (except gas) are figured on a basis of 30 days.

Comparing these costs, the fact appears that the entire 42 miles of railway is now being operated for about $31.00 per day, or $1.67 per operating hour. The interurban system, running alone, averaged about 0.11c per ton mile, or 3.8c per car mile total operating costs. With the city system serving to increase the load factor on the plant the total operating cost per ton mile was reduced to 0.05c, practically half, and the cost per car mile to less than 1c. Comparing these costs with those of independent operation of alternating-current and direct-current plants respectively, a net saving in fuel of approximately 20 per cent. has been realized. It is interesting to note that interurban cars alone require 89 cubic feet gas per car mile, or 2½ cubic feet per ton mile; at present the average gas consumption is 26 cubic feet per car mile and 1½ cubic feet per ton mile. A fuel bill of $10.00 to $12.00 a day for 42 miles of road clearly indicates the economy of gas power, especially with the price of gas equivalent to $4.00 coal. Further, note that the effect of shortening the schedule with a third interurban car is barely noticeable on the expense sheet, but it occasions a considerable reduction in mileage costs—from 10 to 15 per cent. These figures, although not as accurate and comprehensive as could be desired, yet are significant of the general all-around commercial efficiency of the system as installed at Warren.

THE UNION SWITCH AND SIGNAL COMPANY*

H. G. PROUT

First Vice-President and General Manager

THE Union Switch and Signal Company was incorporated in 1882. It was the union of the old Toucey and Buchanan Interlocking Switch and Signal Company, of Harrisburg, and the Union Electric Company, I think it was called, of Boston. The former company was organized as far back as 1878, possibly a year or two before that. That company was organized for the purpose of making and installing interlocking apparatus, for the interlocking of switches and signals, and that was in the very dawn of that art in this country. It began here in 1876, when the first interlocking machine was brought over from England and installed, at the time of the Centennial Exhibition in Philadelphia. These two companies had begun the manufacture, in a crude and simple way, of mechanical interlocking and of electric apparatus for automatic signalling.

I am not sure whether or not it is appropriate for me to tell you a few facts about what interlocking is, but I will venture to do so. The beginning of it was assembling in one place the levers by which one man moved the switches and signals at some distance away. The idea was that one man would be able to do in this central cabin the work that a number of men had been doing out on the ground. Furthermore, there was the advantage of having control from one central position of the throwing of switches and signals. The next step was to interlock these levers so that by motion of a light bar lengthwise of the machine, the levers could be locked in such way that they could be only moved in proper sequence. It became mechanically impossible, by interlocking, for a man to give a signal to permit a train to go over any route except that route which was set up. Movement would be stopped by a danger signal until the switches were set up and after that was done the lever man could pull over the lever which gave a signal to permit the train to pass, and by doing so he locked the other levers in such way that a signal for a conflicting route could not be given. This is a simple and elementary statement of the theory of interlocking. It is much the same as if the keys of a piano were connected mechanically in such way that you could not make a discord. So, therefore, by the interlocking of these levers in one central place you not only enable one man to do at that central point the work of a good many men on the ground, but you make it safe so long as the signals are obeyed.

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*This article is a revision by the author of a paper delivered before a private gathering of business associates.—See editorial comment.

This early work was all mechanical interlocking, as we call it. Motion was communicated from the levers to the signal or switch by a man pulling over levers. After Mr. Westinghouse got interested in this matter, with the amazing foresight that he has, that great grasp of the future, he recognized the practicability of moving switches and signals by some power other than man power; and so he and those associated with him in the Union Switch and Signal Company, began the art of power interlocking. I doubt if any of the foreign inventors were as early in this field as the Americans were, and power interlocking has been perfected in America far beyond anything dreamed of abroad. That is the natural sequence of our conditions, in a certain way. It is the consequence of one of those philosophical facts regulating the development of manufacture and industry in this country. We have been driven to save manual labor by high wages paid for skilled labor; so Mr. Westinghouse and his associates very early began the development of power interlocking, which means that they communicated motion to the switch out on the ground, or to the signal, as the case may be, by compressed air. The air is distributed from a compressing station by pipe lines and tapped off to the cylinder actuating the switch or signal. The air is admitted to the cylinder where it does its work, by valves controlled by electricity from the central station by moving a lever or a push button. That is peculiarly the invention of Westinghouse and his associates in the Union Switch and Signal Company, and is known as the Westinghouse electro-pneumatic interlocking system.

The inventors of America also conceived the idea of making a train set its own signals and protect itself as it moves through a block section. That is accomplished by an extension of the same idea that was carried out in the electric pneumatic interlocking system. Current flowing through the rails in an insulated block section energizes a relay which holds open a valve which keeps air pressure in the signal cylinder and so holds the signal clear. When a pair of wheels goes into that section they shunt the track circuit and it is cut out from the controlling relay and the air is exhausted from the cylinder which holds the signal clear, and the signal goes to danger by gravity and continues at danger so long as the train is in this block section.

That was a very early development of automatic signalling, and to-day is used extensively. Practically all the automatic signalling on the Pennsylvania railroad is electro-pneumatic, and it is used also very considerably on other roads. But the next step forward in the art was the use of electricity instead of compressed air as a motive power. Instead of using an air cylinder we introduce a little electric motor and the circuit through the rails controls the operation of this motor, which clears the signal.

This method of automatic signalling has advanced with tremendous rapidity. The Union Switch and Signal Company brought out its first electric automatic semaphore signal in 1897. Then the first installation of these signals was made and up to the middle of March of this year we had shipped or taken orders for over 15 500 of these automatic electric semaphores. In fact, the orders we booked in the first two months of this year exceeded all that we sold in 1905; and in the year 1905 and up to the present time of 1906, I suppose we have sold more automatic electric signals than we sold in all the preceding years of the company's history.

The electro-pneumatic signal is not advancing proportionately. I suppose our total sales of electro-pneumatic signals are about half as great as of the others. That arises from the fact that the cost of the installation of the electro-pneumatic signal is more than the first cost of installation of the electric signal, as it is necessary to have the compressor stations at comparatively frequent intervals and the pipe for distributing the power. But the electro-pneumatic signal has the great advantage of the extreme simplicity and durability of the working parts, and also the advantage of having a considerable amount of reserve power, so that where railroads can afford to put it in, it is preferred. There is, for instance, on the Pennsylvania railroad a great amount of 4-track line and the first cost and the cost of operation of this apparatus when it is distributed over a great number of traffic units, becomes comparatively insignificant, but for an ordinary double track road the electro-pneumatic signal is seldom installed.

Somewhat the same reasons prevail in the choice between electro-pneumatic and electric interlocking, but in the biggest yards where the conditions are most critical and where it is of vital importance that everything should be durable and reliable, electro-pneumatic interlocking is preferred.

The development of the electro-pneumatic interlocking has advanced from the very simple interlocking I suggested a little while ago to its culmination in the installation which we made at St. Louis, just at the beginning of the Exhibition. We put in a plant there to replace an old one which had become inadequate, and installed an electro-pneumatic machine of 215 levers which does the work of 800 mechanical levers. That is the biggest machine yet installed.

The Union Switch and Signal Company passed through a period of severe struggles, because it was doing for a good many years missionary work and development work. The railroads of the United States would not accept interlocking as a necessity by any manner of means, nor did they accept block signalling as a necessity, and it took a great deal of patience and heavy investment to educate the roads up to the fact that it was advantageous for them to use these safety appliances. Furthermore, the development of power interlocking and automatic signalling, of which I have been speaking, cost a great deal of money, and the result was that for years the company struggled hard. Finally the returns began to come in and now we are getting the benefit of the seed that was sown. Last year we did an aggregate business of three million dollars, and this year we hope to do considerably more.

The product turned out by the Union Switch and Signal Company is extremely varied. It would be difficult for you to imagine how varied our product is unless you could go through our shops. We make all our electrical apparatus, except certain substation apparatus of considerable size. We are now turning out 600 relays a week and turning out 50 complete automatic electric semaphores a day. That involves pretty high-class electrical work. We of course make a great deal of simple product. For instance, our foundry melts about 60 000 pounds of iron a day, and we have a large forge shop.

Our shops at this moment have about nine acres of floor space and we are employing on our rolls at the shops a force of 2 000 men, and have 600 men at work outside on installations.

Now, as to our commercial relations with the railroad companies. We make contracts for the installation of complete equipments of interlocking or of block signalling. We make lump sum contracts and undertake to install and deliver the goods ready to go to work for a lump sum. That, until quite recently, has been almost the only form of contract we have made; but within the last two years we have been developing more and more the percentage contract idea, which introduces the professional element.

We do now a pretty good business in selling material for new and complete installations right at our door. Railroad companies are now installing for themselves and that has come to be a considerable practice. That has only been possible, however, within recent times, for the reason that the men competent to do that installation work have not been at all readily obtained outside of the ranks of the Union Switch and Signal Company. In fact, a considerable percentage of the signal engineers of the companies at this time are men who have been educated in our shops and offices. We furnish a stream of such men to the companies, but at the moment we have not enough men for ourselves. The art is developing so rapidly that I apprehend within the next six months we shall have more difficulty in getting competent men than we shall have in delivering the material from our shops.

That leads me to say something about the signal engineer himself. The signal engineer has up to a very recent time not occupied the position in professional estimation that he is entitled to. That is the result of a good many things; but it is to a certain degree the result of the fact that the railroad officers themselves approach this matter of signalling and interlocking from a somewhat wrong standpoint. They look upon it merely as insurance, and everybody hates to pay for insurance, and everything connected with insurance is a nuisance. The fact is that it should be looked upon as a means of increasing the earning capacity of the railroads. That is to say, on a properly signalled road you can get more work out of a unit of track than you could if it were not properly signalled; and the same thing holds true to a greater degree in a big yard. It has become now fairly well recognized that a great yard cannot be worked economically or advantageously without power interlocking. So, as I say, there is a misconception on the part of many railroad officers as to the true function of signalling and interlocking, and this has been to a considerable degree responsible for the fact that the signal engineer has not had the recognition and the professional position to which he is entitled.

Proper block signalling on every railroad is a problem by itself, and the proper block signalling on each division of any railroad is more or less peculiar to itself. There are a great many conditions that have to be studied in order to get up the most efficient scheme of block signals. There are the grades, the curves, the maximum speed of trains, the nature of the traffic, all these things have to be considered. It will be obvious to you at once that the block signals have to be spaced somewhat with a view to the maximum speed of the trains working over a given piece of track. You must have stopping distances. A communication was written by Mr. Westinghouse a few years ago, and published in the journal of which I was then editor, designed to point out that under the conditions then existing, and in fact existing to-day, as far as braking power goes, the signalling of the best of the roads was inadequate for very great speeds. He pointed out that if a man were called upon to stop his train from a speed of 90 miles an hour on a level track with a dry rail, at the end of 16 seconds he would have run 1 800 feet and would still be running at 61 miles an hour. The laying out of the blocks must be a function of the maximum speed. But if you make the blocks very long you at once limit the number of trains passing over the road because your trains must be spaced the length of a block apart; so to properly judge how you are going to get the maximum train movement for any given bit of railroad, giving the conditions obtaining on that railroad, becomes a nice piece of civil engineering. That problem was a very pretty one in laying out the signalling of the subway in New York.

But when you come to the proper interlocking of a great complicated yard, the situation becomes even more serious and complex, and it requires considerable experience and some power of analysis to lay out the tracks and signal up the yard, fixing the routes so as to get the greatest efficiency out of that yard. That is all within the province of the signal engineer, and he is qualifying himself to a considerable extent to become transportation officer, and one line of promotion on the great railroads will be from the signal engineer to the transportation department. Then again, the signal engineer, as the art is developing now, has gotten to be a pretty good mechanical engineer and an electrical engineer besides. Recognizing some of these things, we have introduced an apprenticeship course at Swissvale.

"Without the various methods of electrical control that have been devised and are in general use, it would be utterly impossible for the great railways of the world to carry one-half the traffic they they are now dealing with daily with safety and despatch. In this branch of electrical work steady progress is being made, and apart from the question of haulage the extension of the methods of electrical control will probably be considerable in the immediate future." Inaugural address of John Gavey, president, The (British) Institution of Electrical Engineers.

THE ROLL MOTORS OF AN ELECTRICALLY OPERATED RAIL MILL

B. WILEY

RAIL MILL No. 3, at the Edgar Thompson Works of the Carnegie Steel Company, has the distinction of being the first rolling mill entirely equipped with electric motors. These motors are of the 220-235 volt, direct-current type. There are two main motors of 1 500 hp each, driving rolls and 18 other motors ranging in size from 25 hp to 90 hp on the auxiliary equipment used in rolling. The general arrangement of the mill proper is shown in Fig. 1. There are two trains of rolls No. 1 and No. 2, each of which is direct-connected to a 1 500 hp motor. Each train consists of two sets of rolls and all except the outside set, or finishing pass of No. 2 train, are three high. There are tilting tables at the No. 1 rolls to convey the pieces from the bottom to the top passes and an inclined table to guide the pieces into the bottom pass after leaving the top pass of No. 2 and No. 3 rolls. The remaining equipment of the mill proper consists of heating furnaces, drawing machines and roll tables, marked A, B and C respectively. The omitted apparatus consists of hot saws, cooling beds, straightening presses and drills, these being located in the lower part of the mill.

THE ROLL MOTORS

The roll motors are duplicates and are of the two bearing type as shown in Fig. 2. They were furnished by the Westinghouse Electric & Manufacturing Company and are direct-current, 1 500 hp, 30 pole, 235 volt, compound-wound with 15 per cent. series field excitation; and have a normal range of speed from 125 r.p.m. at no-load to 100 r.p.m. at full-load.

Particular attention was given in the selection and design of the motors to the question of capacity and mechanical strength. The shaft is 28 inches in diameter at the fly-wheel and the bearings are 25 inches in diameter and 62 inches long. They are lined with Babbitt metal, and although of the oil ring type, are water cooled. This is an extra precaution against an accident due to heating, as the oiling alone gives good service. A large babbitted thrust collar is mounted on the shaft on the outside bearing next to the mill. The outer end wall of this bearing is five inches thick and acts as a seat for the collar. This arrangement provides for the end thrust which might occur should there be a diagonal break of the shaft in the mill.

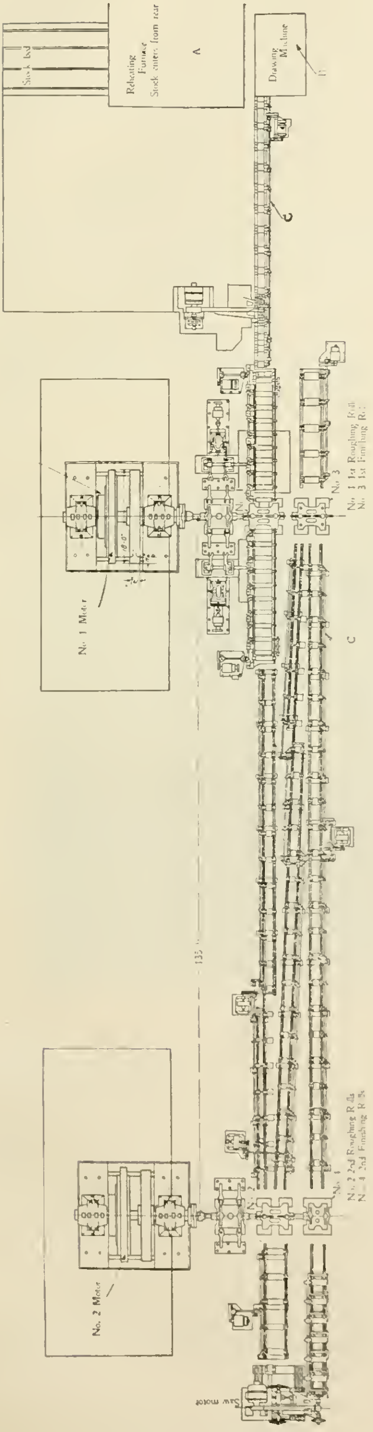

FIG. 1—PLAN OF MILL

If this thrust was not provided for in some way serious damage to the motor armature might result.

A heavy cast steel fly-wheel of the segment type is mounted on the shaft next the armature on the mill side. It weighs 125 000 pounds, is 18 feet in diameter and at 130 r.p.m. has a peripheral speed of 123 feet per second. The radius of gyration is approximately 6.75 feet.

There have been many cases where the motors selected for mill work have proven too small and it has been necessary to install larger machines. Although the capacity of the original motor might have been sufficient for the normal load, the excessive electrical and mechanical strains due to the reversing of the motor caused trouble. In other cases the location was not favorable and external heat and dirt caused breakdowns. As a result of these experiences there has been a growing tendency to use a more liberal safety factor in selecting motors for steel plant work.

These roll motors are examples of what is considered good practice in this respect for both the mechanical and electrical features have been given generous consideration. This statement has been verified by actual practice during the eight months of operation — as no trouble has been experienced.

SWITCH BOARD AND STARTING DEVICES

A switch board and starter as shown in Fig. 3 is provided for each motor. The starter was deesigned and built by the Cutler-Hammer Company and is composed of twelve large, special type hand switches, so arranged with a mechanical interlock that it is impossible to close them except in their proper order. To prevent the motor from racing, two shunt field relays are so arranged that one of the circuit breakers and all of the starting switches will be tripped in case the shunt field circuit of the motor is opened while the motor is running. To prevent injury from excessive speed each motor is provided with a centrifugal speed limit device placed on the outer end of the armature shaft and mechanically connected to one of the circuit breakers by a series of linked rods. As a further protection the second circuit breaker is provided with a no-voltage coil which opens the motor circuit in case of failure of the line circuit,

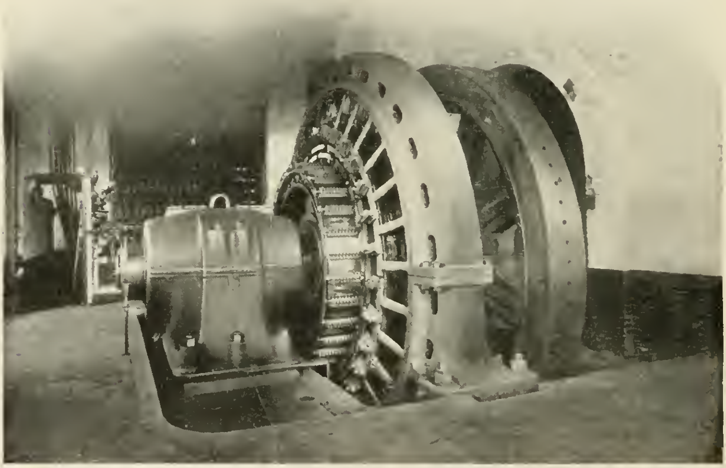

FIG. 2—1 500 HP MOTOR INSTALLED

Each motor is provided with a separate resistance of unusual design, the steel mill idea of steadiness and reliability being well exemplified. Each bank of resistance consists of 105 thirty foot lengths of 25 pound steel T-rails and 295 lengths of 40 pound rails. The supporting rack is also constructed of rails and insulated by special shaped fire brick. The capacity of the resistance is such that the motors can be run on any desired point of the resistance without undue heating.

OPERATION OF THE MILL

No. 3 mill was designed originally to re-roll discarded T-rails of an imperfect section (commonly called seconds) into smaller sections. Thus rails weighing 50 to 90 pounds per yard are reduced to either 16 or 20 pound sections. It was found that the supply of seconds was not sufficient to keep the mill in continuous operation and the scheme of rolling the smaller sizes of T-rails from square billets was developed, the sizes of billets for the 16 and 25 pound sections being 2¼ by 2¼ inches and 3½ by 3½ inches respectively. The length of the stock in all cases ranges from 16 to 20 feet and the finished product is generally in three thirty foot lengths.

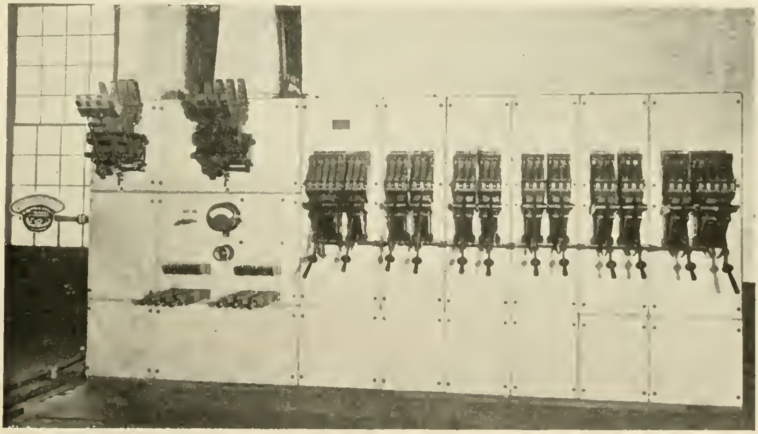

FIG. 3—FRONT VIEW OF SWITCHBOARD FOR ONE THE 1 500 HP MOTORS

The stock is fed into the natural gas heating furnace at the rear by a motor driven pusher; and, after the heating period, it is removed by a drawing machine and carried to the rolls by the roller tables. Fig. 4 gives the passes for the re-rolling process in a diagrammatic form. Nos. 1, 2, 3, 6 and 7 passes are made in the first set of rolls and Nos. 4, 5 and 8 passes occur in No. 2 train.

TEST READINGS

A series of tests were recently made on No. 1 motor. The purposes of the test were:

First—To determine the general working condition of the mill as shown by simultaneous readings of the current, voltage and speed for successive conditions in regular operation.

Second—To obtain readings of the cycles of operation during the reduction of the rails and to plot these cycles just as they occur in their over-lapping stages in order to show the power requirements for the different periods.

Third—To determine in a general way the value of the fly-wheel as an equalizer of the motor load.

For this last case in particular, continuous curve readings of the speed and power were very desirable. Fly-wheel data can be obtained only when the rate at which the power is stored up or given out can be ascertained. Continuous reading instruments were not available, but it was decided that practical data could be obtained by plotting curves from of five second readings of the speed and load. The results as shown in Fig. 5 give a good idea of the average conditions of rolling.

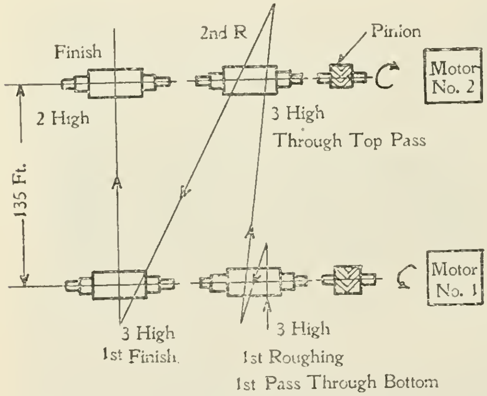

DIAGRAM OF PASSES

Fig 6 gives a diagram of the connections of the instruments used. The milli-voltmeter MV was calibrated with the switchboard ammeter shunt and a multiplier was used to obtain the ampere readings. All the instruments used were such as are commonly found in electrical and mechanical testing outfits.

The readings of current and speed, and the number of the passes occupied were noted every five seconds for a period of five minutes per run. Wattmeter readings were taken at the beginning and end of each run and the friction load of the mill running light was noted. A recording voltmeter gave a check on the line voltage. A series of readings was taken to determine the cycle of operations of one rail as it passed through the mill and a standard chart was plotted, showing the time that the piece was in and out of the rolls from the first to the eighth pass. This standard chart proved to be an excellent means of checking the layout of the pass charts of the various sets of readings. The chart for run No. 13 is shown in the lower part of Fig. 5. The observations gave only the passes occupied at the five second intervals. These periods were marked and the standard chart applied to complete the diagram.

As there were at least five and sometimes seven points in common, the standard chart could be superimposed on the observed readings within a very close range of the true position.

Fig. 5 also shows the current and speed readings in plotted curves. As the voltage remained practically constant the curve as recorded by the voltmeter was not drawn. When there is but one piece in the mill the current varies from 2 500 to 3 500 amperes, the first few passes being the lightest loads. During the test there was an average of six pieces in the mill at the same time and occasionally the maximum load on No. 1 motor included three passes. It required approximately two minutes to roll one piece; and, at this rate, the capacity of the mill is 4 800 thirty foot rails in twelve hours, allowing 75 per cent. of the period as actual working time. The power required to roll 15 pieces of 90 lb. rail to a 16 lb. section during the five minute run was 90 kilowatt-hours, including an 1 800 ampere friction load of the mill. This gives an average of 56 kilowatt-hours per piece. When billets are used as stock this section requires only 47 kilowatt-hours. The friction load varies from 1 200 to 1 800 amperes at 230 volts according to the way the mill is keyed up. A maximum working load of 6 000 amperes is occasionally reached but this is well within the range of the motor. The excessive loads occur when the stock is not well heated or when it cools below the proper rolling temperature, due to a delay in the mill. The minimum reading during the test was 3 250 amperes and the maximum reading reached 5 000 amperes, giving an average of 4 700 amperes as figured from the wattmeter readings. In mechanical power developed, this gives a friction load of 500 hp and a working load vary-

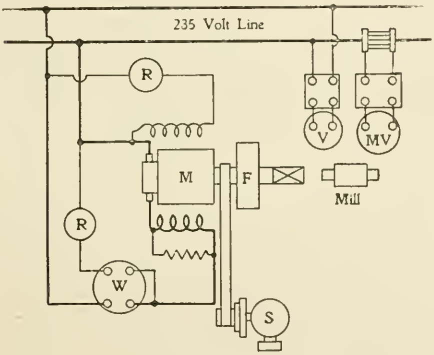

FIG. 6—DIAGRAM OF CONNECTIONS
M—motor; F — flywheel; R — resistance; W—recording wattmeter, 500 amperes, 250 volt, multiplier 500; V—voltmeter; MV—mili-voltmeter; S—speed indicator

ing from 950 to 1 450 hp with an occasional load of 1 709 hp. The fluctuating load at the rolls is considerably greater than this and the

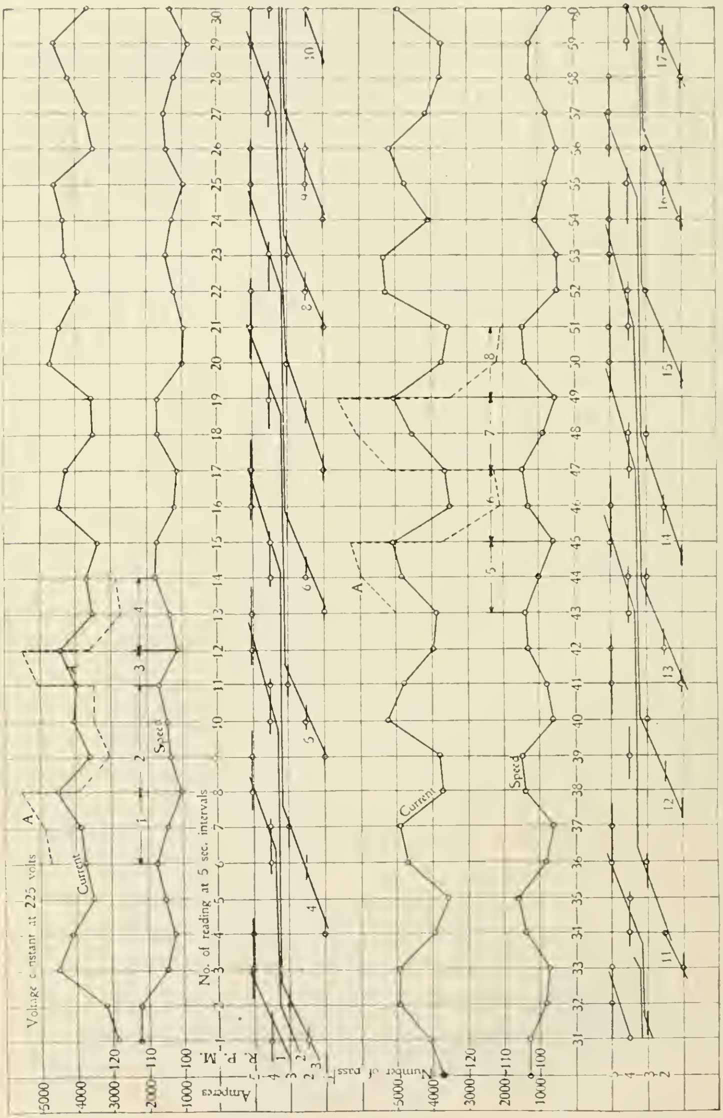

FIG. 5—TEST OF 1 500 HP MOTOR NO 1, MILL NO 3, EDGAR THOMPSON STEEL WORKS

Test No. 13, 90 lb. T-rails re-rolled into 16 lb. T-rails. A 90 lb. T-rail, 5⅜ in. base, 2⅝ in. head, 16½ ft. long makes 2-30 ft. and 1-28 ft., 16 lb. rail, 2¼ in. base, 1¼ in. head with 6 to 9 ft. scrap at each end

equalizing effect of the fly-wheel on the motor load is very pronounced. The motor slows down with an increase of load owing to the inherent speed regulation due to the compounding. During this period the fly-wheel gives up energy and assists in driving the mill. When the load is decreased the motor speed increases and stores energy in the fly-wheel. The ideal cycle of operation is obtained when the period of maximum load in the mill is accompanied by a reduction in speed from the maximum to the minimum limit so that the fly-wheel may contribute the greatest practicable amount of energy, thereby reducing the load upon the motor. The intervals of light load in the mill should allow the motor to accelerate the fly-wheel to the highest speed. The tendency of the fly-wheel is therefore to produce a constant motor load, and thus allow the use of electrical equipment of smaller size and to decrease the demands upon the power station.

In case the fly-wheel had not been used the current would have reached the values shown by curves *A* and *B* in Fig 5. These values were obtained by assuming a constant output and intake of fly-wheel energy during the period of slow down and acceleration respectively. The corresponding current values were added and subtracted accordingly from the test readings. These are only approximate quantities but they tend to show the influence of the fly-wheel; and, for the average conditions it can be said that the fluctuations of the motor load are only about one-half of what they would be without the fly-wheel. The curves show a periodic rise and fall of the current at intervals of approximately fifteen seconds between peak loads.

ADVANTAGES OF ELECTRIC DRIVE

The points of advantage over steam and hydraulic power directly applied are: Low operative cost, reliability and flexibility of speed characteristics. By various rheostatic combinations a number of speeds can be obtained with little sacrifice of efficiency, a condition which is not true with steam equipments.

A central electric station equipped with gas engines using blast furnace gas is the most economical arrangement for a steel plant. Gas engines are not well adapted to variable speed and reversing under the conditions of load such as that required in direct-connected rolling mill work. Hence it is necessary to interpose flexible speed drive regulation between the engines and the mill. This is the principal function of the electrical equipment, as by its use the station load can be made practically constant.

TESTS OF LARGE SHAFT BEARINGS

ALBERT KINGSBURY

THE operation of bearings of large generators in which the rotating weights are very heavy and the speeds are high involves problems which are not within the range of ordinary practice. When it was suggested to run the 5 000 kw generators which were proposed for the Niagara Falls Hydraulic Power & Manufacturing Company, and which were to have rotating fields weighing approximately 100 000 pounds, at a speed of 300 revolutions per minute, the engineers of the Hydraulic Company felt that the work should not be undertaken until tests were made. As a result special apparatus was built at the request of the Hydraulic Company and the tests were made under the direction of the author at the works of the Westinghouse Electric & Manufacturing Company.

The apparatus, as shown in Figs. 1 and 2, consisted of a horizontal shaft supported in two bearings each nine inches in diameter thirty inches long, with a third bearing fifteen inches in diameter and forty inches long midway between the supporting bearings. The fifteen inch bearing was pressed upward against the shaft by means of a lever made from two fifteen inch I-beams weighted at its outer end. The nine-inch bearings each carried half the load, less half the weight of the shaft. These three bearings are designated *A, B* and *C*, beginning at the left in Fig. 1. The shaft was driven by a Westinghouse No. 50 (150 hp) direct-current railway motor; for shaft speeds not exceeding 500 r. p. m., the motor was mounted as shown in the figures, with 21-teeth and 50-teeth gear; for higher speeds the motor was mounted on the floor, with a twenty-six inch pulley on the armature shaft and twelve inch pulley on the test shaft, driving by an eight-inch double leather belt. The electrical power supplied to the motor was the only available basis for estimating the friction of the bearings, the motor efficiency being approximately 67 per cent at 45 to 54 amperes, and 85 per cent at 114 to 127 amperes. The total power consumed by the bearings *A, B* and *C* was approximately determined, but their separate frictions could not be found.

The shaft journals were made true with lead laps and finished with emery cloth. The bearings were lined with genuine babbitt metal, scraped to fit the shaft. The clearance over the top and sides was about .03 inch in *B*, and this proved to be ample. The vertical

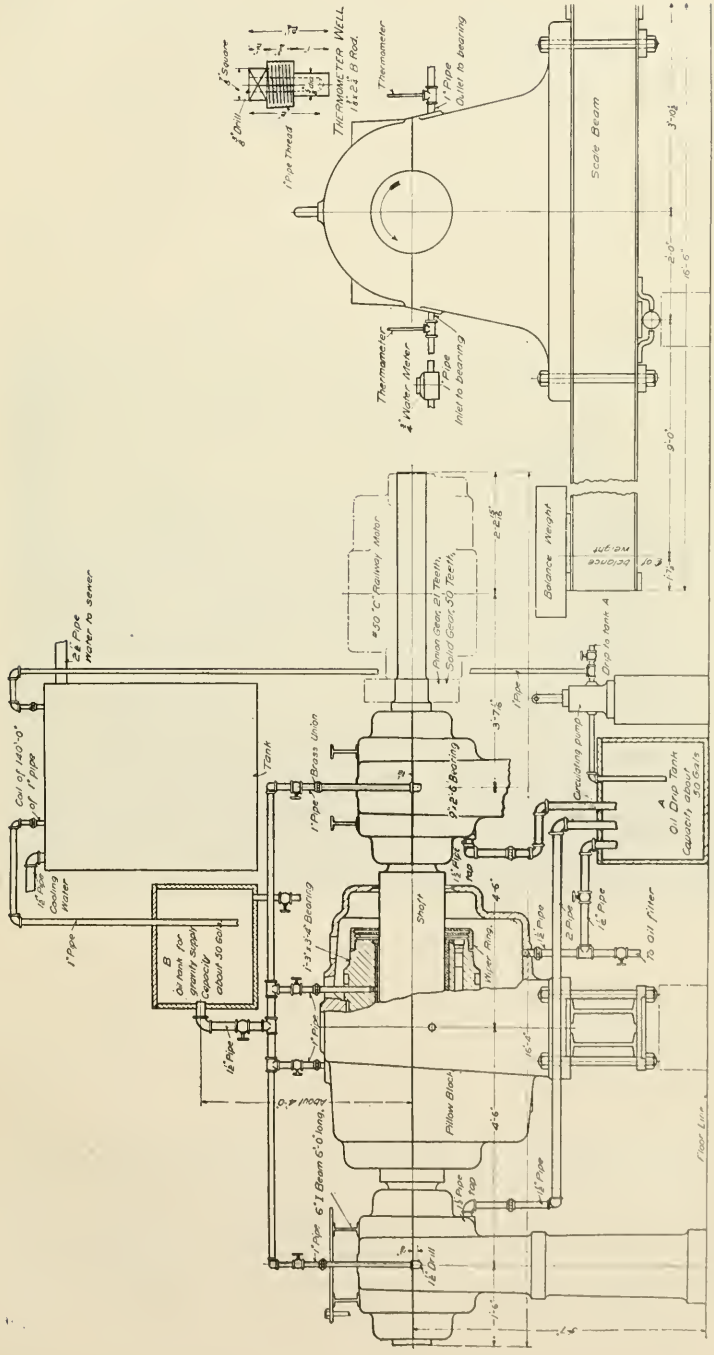

FIG. 1—SKETCH SHOWING ARRANGEMENT OF BEARINGS AND APPARATUS FOR BEARING TEST

clearance in *A* and *C* was but .007 or .008 inch and was not enough to provide for the expansion of the shaft and inner part of the bearings under the rapid heating of the most severe tests. The bearing sleeve of *B* was cored for water cooling; the lower half only was connected for water circulation, with thermometer wells at inlet and outlet, and with a one-inch water meter at the inlet.

The bearings were flooded with oil from a small supply tank. The drip was returned to the tank by a motor-driven pump, through a coil of 140 feet of one-inch pipe, with provision for water cooling, as desired. The oil supply pipe to each bearing was connected into a wide and deep groove in the face of the babbitt, parallel to the shaft and extending nearly the full length of the bearing. The groove was located at the top of the bearing in *B*, and at the side in *A* and *C*.

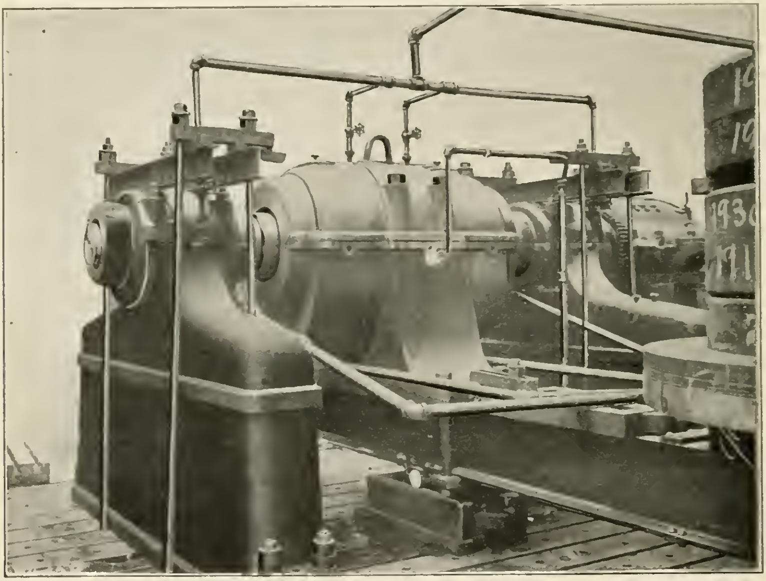

FIG. 2—VIEW SHOWING ARRANGEMENT OF BEARINGS AND APPARATUS DURING TESTS

The test runs were generally of about seven hours duration each day, starting with all parts cool, and bringing the shaft up to full speed as quickly as possible. If the speed was quickly raised to about 1 000 r. p. m. it was found that the expansion of the shaft and inner part of the bearings caused binding, particularly in the bearing *C;* hence to reach the higher speeds it was necessary to accelerate slowly allowing at least three hours for heating the outer parts. The load was relieved at starting because of the very great torque that would be required for starting under load.

Bearings *A* and *B* became somewhat damaged apparently from raising the speed too rapidly in the final run (No. 13), Table I, in which a speed of about 1 350 r. p. m., was attained within four and one-half hours, including a stop of one and one-half hours, the load being 101 000 lbs.

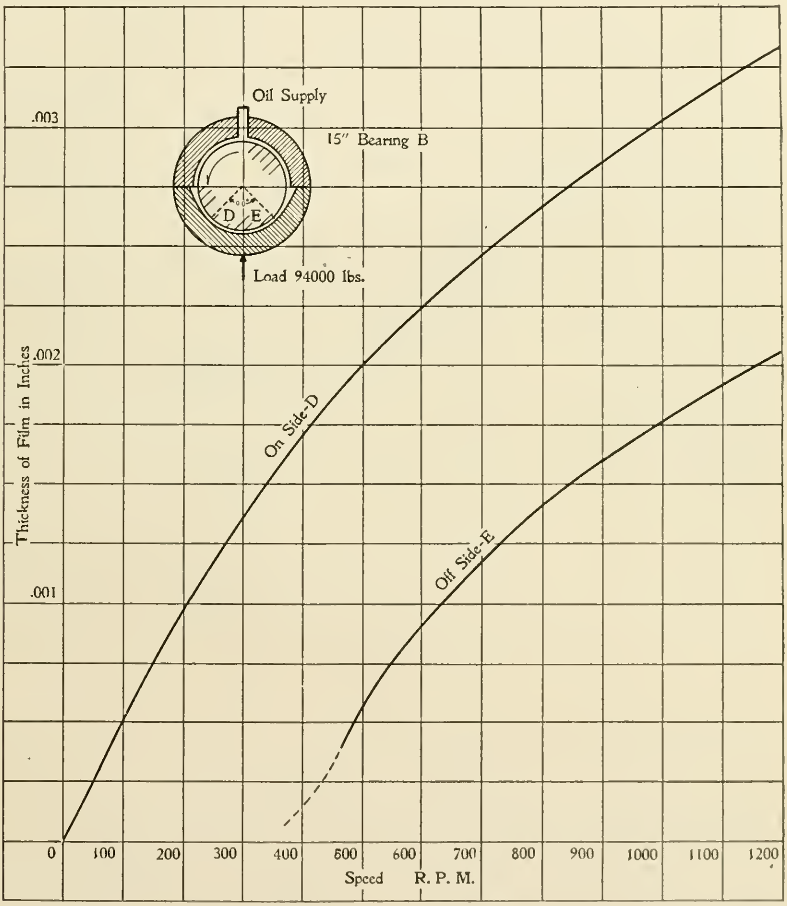

FIG. 3—CURVES SHOWING THICKNESS OF OIL FILM AT POINTS *D* AND *E* AT VARIOUS SPEEDS

The thickness of the oil film between the shaft and the bearing *B* was measured at successively reduced speeds under a load of

94 000 lbs. at the close of test run No. 12. Four "Bath" lathe indicators were used for this purpose, two being attached to each end of the housing, with contacts on the shaft at the positions *D* and *E*, respectively (Fig. 3). The relative displacement of the shaft and

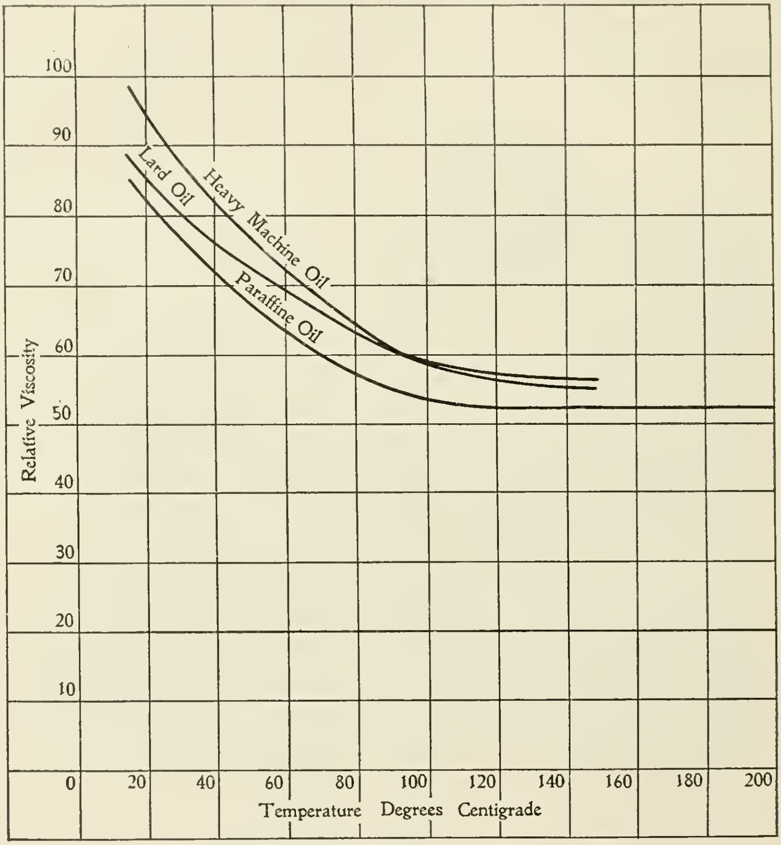

FIG. 4—CURVES SHOWING RELATIVE VISCOSITY OF HEAVY MACHINE OIL, LARD OIL AND PARAFFINE OIL AT DIFFERENT TEMPERATURES

	Spec. Grav.	Spec. Heat (approx.)
Heavy machine oil	.92	.547
Paraffine oil	.89	.551

bearing by the oil film, as shown by the curve (Fig. 3) is greater at *D* than at *E* at all speeds; a condition which as theoretically proved by Osborne Reynolds, "Theory of Lubrication," Phil. Trans. 1886,) is essential to complete lubrication and is automatically maintained. The speed could not be controlled below 400 r. p. m. but the rapid increase of friction due to imperfect lubrication occurred at about 300 r. p. m. as the speed was reduced. The lower limit of speed for complete lubrication might be expected to be determined by the conditions in the bearing *A* or in *C*, or both, rather than by those in *B*; nevertheless the curve for the point *E* appears to show that the metals in *B* came into contact at about 300 r. p. m., the apparent speed limit.

A and C—9″ by 30″ B—15″ by 40″		Temperature of bearings constant*								Tests with paraffin oil		
		Tests with heavy machine oil										
Test number		3	4	5	6	7	8	9	10	11	12	13
Load on B tons		25	25	25	25	25	25	33.6	42.3	47	47	50.5
Press. on B lbs. per sq. in., nominal area		83	83	83	83	83	83	112	141	157	157	168
Load on each A and C tons		11.1	11.1	11.1	11.1	11.1	11.1	15.4	19.7	22.1	22.1	23.6
Press. on A and C lbs. per sq. in		82	82	82	82	82	82	114	146	164	164	175
Shaft speed	R. p. m	306	309	506	180	179	301	454	480	946	1243	1286
	Ft. per min. B	1200	1215	1990	708	704	1180	1785	1890	3720	4900	5050
	Ft. per min. A and C	720	730	1190	424	422	710	1070	1130	2220	2930	3030
Motor:	Amperes	53	54	57	51	45.5	49.5	51	53	122	114	117
	Volts	253	260	428	141	126	227.5	350	379	301	368	392
	Electrical h.p	18	18.9	32.7	9.68	7.7	15.1	24	26.9	49.3	56.3	61.6
Friction h.p. total for A, B and C		12	12.6	21.7	6.43	5.12	10.1	16	17.9	41.9	47.8	52.3
Friction torque, lbs. ft. total A, B and C		206	214	225	188	150	176	185	196	233	202	213
Average coef. of friction for A, B and C	Starting (cold)	.121	.146									
	Running	.0044	.0045	.0048	.0040	.0032	.0037	.0029	.0024	.0025	.0022	.0022
Temp. Centigrade: Atmosphere		17	18.7	20	20.4	20	16.8	17.3	19.7	20.5	20	19
Top sleeve of bearing	A	48.8	44.9	54	35.8	42	44	52.2	52.9	58.7	74	97
	B										67	58
	C	47.5	45.9	55	40.5	45	45.1	57.8	54.9	67.2	91	117
Oil supply		24.6	12.4	17.7	9.4	†32.5	11.7	14.7	16.4	21.7	20.6	16.5
Oil Drip	A							46.9	47	58	72	65
	B						40.7	49.2	51.3	56	61.5	51
	C							46.8	49.5	59.5	66	62.5
Cooling water for bearing B	Supply	7	6.3	7.6	8.1	19.2	10.9	10.9	11.8	11	12	16
	Discharge	18	13.4	14.6	16.3	32.6	37.9	47.2	48.8	38.5	69.6	69
	Rise of temp	11	7.1	7	8.2	13.4	27	36.3	37	27.5	57.6	53
Lbs. oil supplied per min.	A		4	6.2	3.1	3.9	4.4	6.4	8.2	1.2	9.4	2.8
	B		11.6	11.1	3.1	10.9	41	3.1	5.8	10	7.6	5.9
	C		2.3	4.5	1.5	1.8	2.7	3.8	5	8.5	9.9	10
Lbs. cooling water per min. to B		9.6	13.7	24.5	9.1	.3	.55	.92	.49	6.2	.3	.6
Per cent. of total heat carried A, B and C	By oil							63	80	61.2	61	36
	By water	22.3	19.6	20	29.5	2	3.7	5.3	2.6	10.3	.92	.76
	By air and radiation (by difference)							31.7	17.4	28.5	38.1	63.3

*In 13th conditions were not constant; the data given are those taken just before the bearing seized at speed 1350 r.p.m.

†Oil supply was not water cooled.

As will be seen from the table of data and results of the tests, it was found possible to run the bearings with loads and speeds greatly exceeding the ordinary values in practice, even without water-cooling the bearing sleeve. The extreme case of a successful test is shown in column 12, in which a run was made under 94 000 lbs. load at 1 243 r. p. m., with only a very small amount of water run through the bearing sleeve, merely for determining its temperature. The oil supply, however, was cooled in all the tests except No. 7 and the first half of No. 13.

A NEW TYPE OF REVERSE CURRENT RELAY

P. MACGAHAN AND C. W. BAKER

THE problem of protecting alternating-current circuits operating in parallel against a reversal of the flow of energy, has been one of the most difficult ones in the design of alternating-current power systems. For this purpose, relays have been employed to operate electrically controlled circuit breakers, these relays being of some type which would operate when the current reverses. Heretofore these relays have been of two general types:

The first consisted of some form of magnet wound with two coils, one of which obtained current proportional to the voltage and the other, current proportional to the line currents. These coils, under normal conditions, oppose each other, but when the energy reverses, their effects are additive, thus operating the breaker. The failure of this scheme consisted in the fact that the low power-factor and low voltage present during short-circuits or other exceptional conditions prevented correct operation.

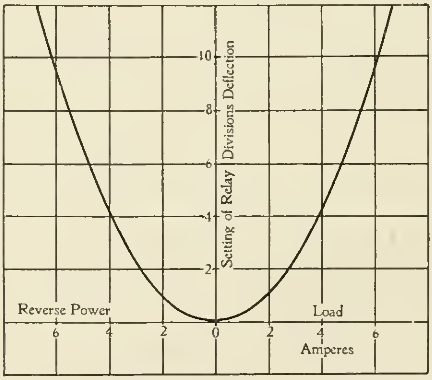

FIG. 1—CURVE OF PERFORMANCE, NORMAL VOLTAGE, UNITY POWER-FACTOR

The second type of relay for this purpose consisted of a wattmeter fitted with moving contacts, which could be adjusted to trip the circuit breaker at any predetermined load in true watts in the direct overload direction or in the reverse power direction. Although somewhat better than the first-mentioned type of relay, it still had the fundamental defect that when the voltage or the power-factor became low, the torque of the wattmeter was also in consequence low, as its torque was proportional to the true watts.

The ideal relay for such a service should consist of such a wattmeter type relay, modified so that it would have practically the same torque at low power-factors as at high power-factors. It should be operative when the voltage becomes zero. It should have the additional features of inverse time element, so as to exercise a selective influence and trip out the circuit in trouble without interrupting the power on those circuits not affected.

Such a relay has been designed and seems to fulfill the required conditions to a remarkable degree. It is used principally for polyphase circuits and consists of two electro-magnets operating two discs mounted on the same shaft, the mechanical construction being very similar to that of the "Type C" Westinghouse polyphase integrating wattmeter. Instead of driving a registering dial, however, the shaft is controlled by a spring and a moving arm is arranged to close a contact connected to the tripping coil of the circuit-breaker. Instead of the electro-magnet being wound with the usual series and shunt coils as in the wattmeter, a special winding is provided which automatically combines the influences of current alone, of voltage alone and of true watts alone. In the absence of voltage the discs are subject only to the influence of current, as in an ammeter. In the absence of current, the relay is in effect operative as a voltmeter. When all these quantities are present in the varying degrees found in practice, there is formed a very effective combination of the three elements, which is taken advantage of to solve the problem of an alternating current and reverse current relay.

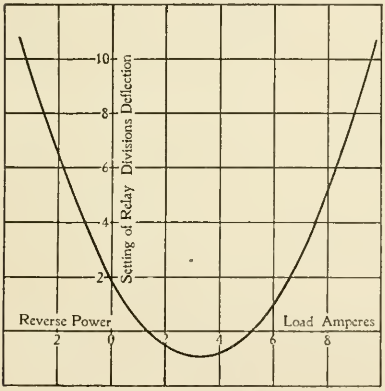

FIG. 2—CURVE OF PERFORMANCE, CURRENT ONLY, ZERO VOLTAGE

The accompanying curves will best illustrate the performance of the relay. In Figs. 1 and 2 the vertical ordinates give the setting of the stationary contacts, and the horizontal lines give the corresponding currents to close the contacts. Values to the right represent power in the normal direction, while to the left are plotted power values in the reverse direction, or power when being fed back toward the generator.

With current only, that is, zero voltage on the line, the relay is an ordinary ammeter type overload relay, whose deflections are proportional to the square of the currents. This is clearly shown in Fig. 1.

It should be noted that all the curves given are the results of actual tests.

With normal voltage and unity power-factor, the curve shown in Fig. 2 is obtained. It will be noted that this curve is similar to the curve in Fig. 1, except that it is shifted slightly downward and considerably to the right, thus giving a negative deflection between 1.6 and 5 amperes. This is the effect of the voltage element of the relay, which acts to deflect the movement in the direction of normal power. It will be noted that for a given setting, a much greater current is required to close the contact when power is passing in the normal direction than when the power is reversed. Note also that the tripping currents in the normal power direction are much greater in this case than in Fig. 1, for the same setting of the contacts. Thus the relay may be set to operate on a very low reversal, but at the same time so as to prevent ordinary overloads from tripping the breaker. Of course, a short circuit would violently reduce the voltage and thus the condition shown in Fig. 1 would hold and the relay would operate.

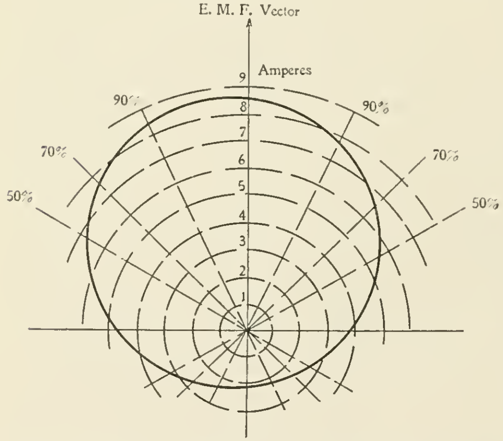

FIG. 3—CURVE OF PERFORMANCE, NORMAL VOLTAGE, FULL-LOAD, VARYING POWER-FACTOR, SETTING 8½ DIVISIONS

The curve in Fig. 2 represents the performance of the relay fairly closely over all working power-factors, say from seventy per cent. leading current to fifty per cent. lagging current. The exact effect of various power-factors with normal voltage and full-load current is clearly shown in the vector diagram, Fig. 3, the tripping currents for a certain setting of the contacts being plotted as vectors and the voltage being vertical.

If the relay is set at 7 (See Fig. 2), eight and one-half amperes will close the contacts at 100 per cent. power-factor. This will represent, say, seventy per cent. overload, the relay operating from series transformers having five ampere secondaries. At this setting, two and two-tenths, or forty-four per cent., full-load current will trip the circuit breaker on reverse power.

It will be seen that the relay may be set to any desired ratio of overload to reverse, by moving the position of the stationary contact. Loops are provided from the windings of the coil, so that absolute values of these quantities for any ratio of overload to reverse can be obtained.

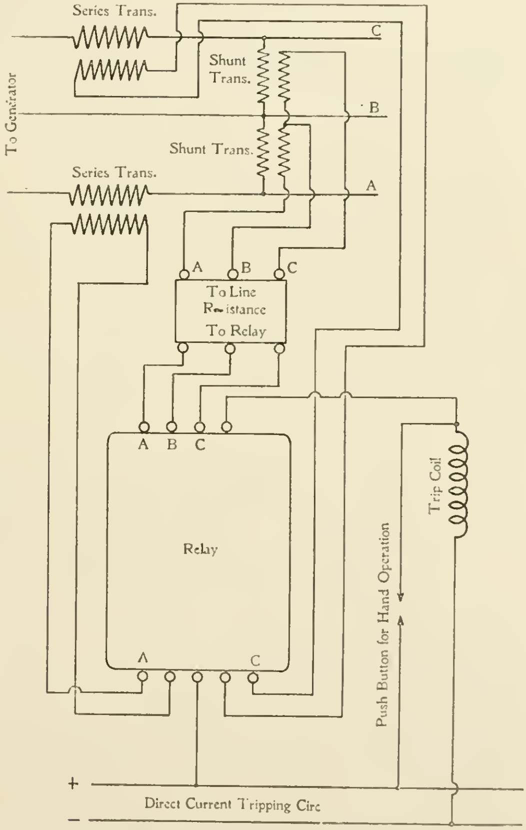

FIG. 4—DIAGRAM OF EXTERNAL CONNECTIONS OF RELAY FOR THREE-PHASE CIRCUIT

There is another adjustment which varies the value of the inverse time element, or damping features of these relays. This adjustment is independent of the other.

In Fig. 4 is shown a diagram of the connections from the relay to the transformers, and in Fig. 5 are shown the internal connections.

A number of these relays have been installed at some of the largest power systems in the country and found to give satisfactory results.

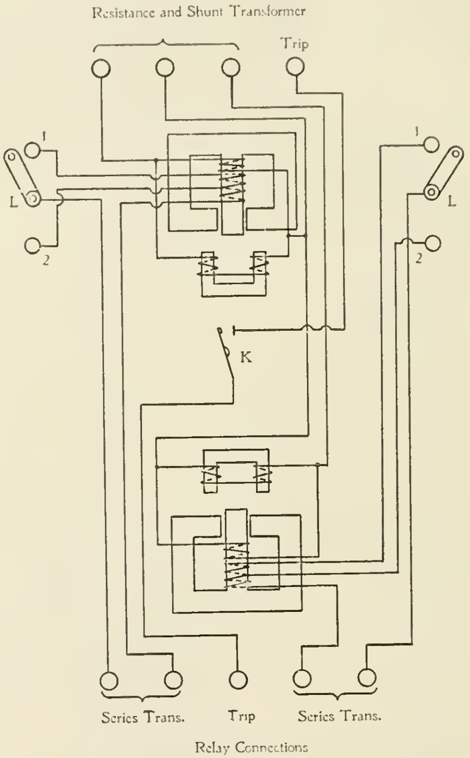

FIG. 5—DIAGRAM OF INTERNAL CONNECTION OF RELAY FOR THREE-PHASE CIRCUIT

Connect links *L* to the contacts *1* for small currents or to the contacts *2* for larger currents. K=contact arm attached to moveble element.

In actual operation, when the tripping coils of the breakers take a large current, an auxiliary relay is provided to save the contacts of the main relay which are designed to carry only about one ampere.

TESTING LARGE MOTORS, GENERATORS AND MOTOR-GENERATOR SETS.—I*

C. J. FAY

WHERE a considerable number of motors, generators and motor-generator sets of large capacity are to be tested to determine the correctness of design and manufacture, it becomes desirable from an economical standpoint, to load them in some other manner than with resistances, water rheostats or prony brakes. These methods of loading not only involve a great amount of power and a generator of large output for supplying current to the generator, motor-generator set or motor, but require bulky rheostats or brakes and large machines for use as motors or generators for driving or loading the machine under test. Beside these, in order to test commercial machines of different capacities, voltages

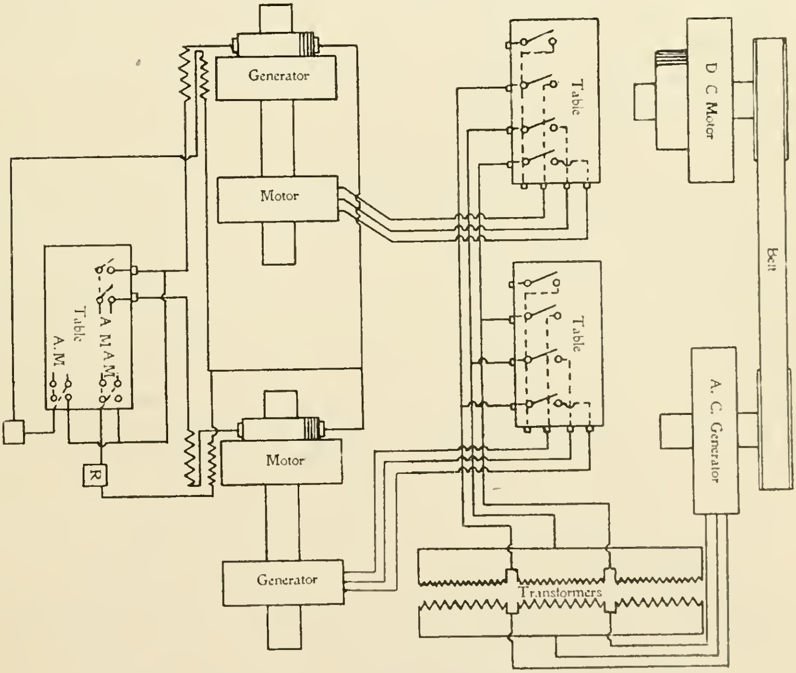

FIG 1—DIAGRAM OF CONNECTIONS FOR MOTOR-GENERATOR TESTING

The shunt fields of both machines are left as for running as generators and the series field of the machine to be run inverted as a motor is reversed and frequencies, large sources of power are required of at least three different voltages for direct-current and two frequencies for alternating-current; and also transformers permitting several ratios and transformers for two-phase—three-phase transformation. If one alternating-current generator is to be used for all alternating-current tests it would have to be designed and set up to run efficiently at several different frequencies.

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*These articles may be considered as supplementary to the series on "Factory Testing of Electrical Machinery" in Vols. I. and II.

To avoid this great expense in testing and equipment, "loading back" methods are resorted to for testing large direct-current motors and generators and motor-generator sets of all kinds. Alternating-current generators and rotary converters are run open-circuited and short-circuited in testing, except in special cases.* Induction motors are loaded by circulating currents through the windings at low voltage.

LOADING BACK MOTOR-GENERATOR SETS

In any loading back test two motor-generator sets are used, but only one of the two sets can be run under normal conditions, the other, in most cases, being run inverted. It is desirable, whenever possible, to obtain two sets of like capacity, otherwise when testing the larger set, the power in excess of the capacity of the smaller set will have to be supplied from some outside source. With direct-current machines unless they are of the same voltage, a booster is required to compensate for the difference in voltage; however, this does not necessarily require a great amount of power, except for very large machines and large differences in potential. With direct-current—alternating-current or alternating-current—alternating-current sets several combinations of alternating current machines may be used. The alternating-current machines may be of any voltage and either two or three-phase, synchronous or asynchronous, providing suitable transformers with the proper voltage ratios are available.

Fig. 1 shows the connections for testing two similar induction motor—direct-current generator sets. This type of outfit is used to illustrate the method of testing as it is met with more often than any other. However, the principle is the same in any case. As an example of such a test figures are here given for a test of two motor-generator sets consisting of two 580 hp, 2 200 volt induction motors direct-connected to two 400 kw, 550 volt direct-current generators. Care must be taken to see that the series field of the direct-current machine, which is to run as a motor is reversed from its normal direction as a generator.

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*These methods of testing have been explained in the articles on "Factory Testing," by Mr. R. E. Workman, Vols. I and II. of the JOURNAL.

When the sets have been connected up as shown in Fig. 1, they are started from the alternating-current sides and brought up to speed and thrown onto the line in parallel. The motors are started at a low voltage and as their speed increases the voltage is raised until full speed and full voltage is reached and the motors are running directly on the line and in parallel.*

The field switches of the direct-current machines are then closed and the generators are allowed to build up to normal voltage. When both machines are at the same voltage the line switches are closed thus throwing the machines in parallel. The set is then ready for load. The current in the shunt field of the direct-current machine, which is to run as a motor is decreased. This increases the speed of that set and drives the induction motor as an induction generator, which in turn supplies power to the induction motor of the other set. This second set runs under normal conditions, the generator supplying power to the machine acting as motor of the first set. The load for a heat run may be brought up to the desired amount by further weakening the field current. Running in this way the two sets are easily controlled by regulating the field rheostats. The amount of external power need only be large enough to start the sets and supply the losses of the two sets under load.

The following table gives readings taken at different loads:

SET NO. 1						SET NO. 2					
Induction Motor			Direct-Current Generator			Induction Generator			Direct-Current Motor		
Volts	Amperes	R. P. M.	Volts	Line Amp.	Field Amp.	Volts	Amperes	R. P. M.	Volts	Line Amp.	Field Amp.
2200	68.7	510	550	0	5.15	2200	67	510	550	0	5.1
2200	211	506	600	668	5.8	2200	167.5	516	600	668	4.7
2200	306	491	587	1002	5.7	2200	230	514	587	1002	3.79

Set No. 1 was run under normal conditions and set No. 2 was inverted.

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*Details of the connections on the alternating-current tables were given on Fig. 56, page 616, Vol. I.

ROAD EXPERIENCE

J. W. SWEENEY

DRIVING OUT TRANSFORMER OIL

AIR, oil and water are the elements generally used to cool transformers. The trouble in the following instance was caused by the latter two elements getting together. The transformers were of 2 200 kw capacity, 60 000 volts primary and 2 200 volts secondary. The trouble was caused by water getting into the circulating coils and freezing before the transformers were installed. This resulted in the bursting or cracking of the water pipes. The fault was not discovered until the transformers were assembled and the tanks filled with oil. When the water was turned on, oil was observed coming out of the pipes with the water.

The top of the transformer was taken off and the bursted pipes located. Repairs were made by wrapping the pipes with No. 14 B. & S. copper wire and soldering the wire to the pipe. The pipe was then tested under 100 pounds pressure and found to be all right. The insulation oil was then examined and found to contain a considerable amount of water. Tests were made by thrusting a hot iron bar into the oil. The hissing sound resulting gave evidence of the presence of water. Some carbide was also put into a sample of the oil and this test also indicated water, judging from the bubbles rising from the surface. The problem was then to dry the oil. The transformer held 1 900 gallons, and there were 100 gallons in the tank, making 2 000 gallons altogether. On making inquiry it was discovered that an outfit for cooking the solution used in treating the cross-arms and pins of the transmission line was still in the vicinity and located about a half-mile away and 200 feet uphill. At this time there was three feet of snow on the ground and the temperature was below zero. Some men were set to work digging the snow away and finding the apparatus. There were two kettles, one inside the other, leaving two and one-half inches space between. These were carried down to the basement of the power house and located in a position as near the supply tank as possible. Then a furnace was built of brick around the kettles. The inside kettle was 36 inches in diameter and the outside one 45 inches in diameter and 50 inches deep. These kettles were fitted with lugs so that the lugs on the outside kettle rested on the brick work and the lugs on the inside kettle rested on the rim of the outer kettle. There were three storage tanks, one 50 inches deep and 108 inches in diameter and two 39 inches deep and 86 inches in diameter. These were connected up to receiving and delivery pipes through a turbine pump operated by a 7½ hp induction motor. Pipes were run from the storage and delivery pipes to the pump and to the kettles. As the damaged oil was in the largest tank this tank was disconnected at the bottom or delivery end and a two-inch pipe connected up to run from the tank to the kettle. This pipe ended at the top of the kettle. When filling the kettle the oil flowed onto a perforated surface instead of directly into the kettle. The pipes for the receiving tanks were connected up and ended at the bottom of the kettle.

After all the preparations were made the space between the kettles was filled with oil, one filling being enough for the entire operation. Then an anthracite coal fire was started in the furnace under the kettles, and the temperature of the oil was brought up to between 100 and 110 degrees centigrade. Then the pump was started up and the oil allowed to flow in at a rate such that the temperature could be kept between 100 and 110 degrees centigrade. If the temperature started to go down the oil inlet valve was partly closed, and if it went still lower than 100 degrees the pump was stopped. When the temperature started to go up the supply valve was opened and the fire decreased. By careful manipulation the pump was kept running constantly night and day until all the oil was run through. There were two thousand gallons to dry out, and it took 38 hours, or an average of 53 gallons per hour. At different stages of the process the oil was tested for water, but none was found. The fact that the work of drying was well done was evident from the fact that as soon as the oil was cold it was pumped into the transformer and a full line pressure of 60 000 volts was put on the transformer without any further trouble.

THE ELECTRICAL NATURE OF MATTER AND RADIOACTIVITY

The following paragraphs constitute the "Conclusion" of the book entitled "The Electrical Nature of Matter and Radioactivity," by Harry C. Jones, professor of chemistry in the Johns Hopkins University, a review of which is given on this page.

"The investigations, of which a general account has been given in these chapters, mark a new epoch in the development of the physical sciences. Some of the results obtained are as important from the standpoint of the physical chemist as from that of the physicist.

"Facts have been brought to light which are of a character that are very different from anything hitherto known. *The existence of extremely penetrating forms of radiation, the instability of the chemical atom, the formation of one elementary substance from another, the existence of a form of matter that can charge itself electrically, that can light itself, and that can give out an amount of heat that is almost inconceivably great,* are some of the facts to which we must now adapt ourselves.

"These are magnificent developments with which to open the new century. Probably still more surprising facts are awaiting men of science before its close. It seems not too much to predict that as the nineteenth century surpassed the preceding eighteen in the development of scientific knowledge and the discovery of truth, just so the twentieth century will exceed them all in the gifts of pure science to the store of human knowledge.

"The wave of scientific investigation for its own sake that has recently swept over the entire civilized earth, must yield a rich harvest to those who shall be permitted to reap it."

BOOK REVIEW

"The Electrical Nature of Matter and Radioactivity," by Harry C. Jones. D. Van Nostrand Company; 8vo., cloth; 200 pp; illustrated; price, $2.00.

The author, who is professor of physical chemistry in the Johns Hopkins University, states that his aim has been to give the more important facts and conclusions in connection with the work on the "Electrical Nature of Matter and Radioactivity" as far as possible in non-mathematical language, and while the work is written in a semi-popular style, an attempt has been made to treat it with scientific accuracy.

sented have nearly always been taken from the original sources and reference is made to the original papers for those desiring to make an exhaustive study of the subject.

The book is an admirable review and summary written in an attractive form of what has been done along advanced scientific lines in recent years. The book is not a popular essay nor a mathematical treatise. A fair knowledge of chemistry and physics is desirable if not essential to the reader. To one whose scientific knowledge is based upon the theories of fifteen or twenty years ago this book is of great interest in showing the advance which has been made and the plausible connection between the old views and those which are more recent.

The titles of some of the chapters indicate the character of the contents more definitely:

Electrical Conductivity of Gases; Nature of the Corpuscle-Electrical Theory of Matter; Nature of the Atom in Terms of the Electron Theory; X-Rays; Discovery of Radium; Production of Heat Energy by Radium Salts; Production of Radioactive Matter; Most Recent Developments in Radioactivity.

C. F. S.

THE

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Testing Railway Motors

The article by Mr. Fay in this issue of the JOURNAL describes certain methods employed in regular commercial testing of railway motors. These tests are entirely empirical and are made simply to determine whether the motors fulfil arbitrary conditions that have been laid down. The generally accepted rating of the railway motor is on a basis of not to exceed 75 degrees C. rise during an hour's operation at a given output, the output being the input at a given voltage and amperage reduced by the efficiency of the motor. As a railway motor is never in practice called upon to operate under these conditions, it is obvious that this test is useful only in establishing a commercial standard rating.

A test that is of vastly greater importance in determining whether the motor will operate on certain given conditions of load, service and schedule speed, is to reproduce the exact operating conditions. Mr. Wynne, in his articles on "Electric Railway Engineering," has described a method of developing the so-called "typical run" for any given service. Having determined the typical run which embodies the rate and period of acceleration, the time of coasting or running without power, the period of braking and the time of standing, the nominal rating of the motor can be established. From this typical run curve the mean value of the current used in the motor, as well as the mean applied voltage extending over the whole time, can be calculated. This determines the current and voltage under which the motor must operate continuously to fulfill the given conditions. It is found in practice, however, that while a motor may operate satisfactorily on the testing stand at this calculated rating, it may not operate satisfactorily in service. This may be due to trouble with commutation from a heavy accelerating current, or to heating of the commutator due to friction on account of high speed, or the heating of the motor may be increased due to iron losses at the different speeds.

In order to reproduce this typical run in a shop test it is necessary that the testing apparatus should embody in its construction a certain amount of inertia which corresponds to the mass that the motor will be called upon to move. With such an arrangement and means for adding a certain amount of friction, which will correspond to the bearing and rolling friction, a motor can be given a shop test which will be practically operating conditions. Such a test, however, need not be applied to all the motors intended for one installation as, having made such a test on one or more of the motors, a commercial test as described by Mr. Fay can be established from the data on the motors so tested.

It has been found in testing motors by this method to conform with different typical runs having the same value of square root of mean square current, that the behavior of the motors is quite different, depending upon the rate of acceleration, time of coasting and other operating conditions.

While it is important that motors should be tested as nearly under operating conditions as possible it is equally important that control apparatus should be similarly tested. A piece of control apparatus may have ample carrying capacity as far as heating is concerned but may not operate satisfactorily when manipulating and rupturing motor circuits. The heating may also be materially increased by the arcing at the contacts. The effect of these conditions can only be determined by operating tests as described.

Experience has shown that while the ordinary commercial rating of a railway motor is some guide to what its performance will be in service, its selection would be a matter of considerable guess work unless it be tested by a method which will give operating conditions or the selection be made as the result of a great deal of experience.

WILLIAM COOPER

The Electric Club

It is probable that the readers of the JOURNAL rarely pause to think of the impelling force which has made this publication possible. The article by Mr. F. D. Newbury on "The Purpose of The Electric Club" in this issue is probably the first intimation which many of our readers have had of the inception as well as the purpose of the Club.

From the standpoint of the management of the Electric Company, there is a phase of the Club work which, while it has been touched upon by Mr. Newbury to the effect that "the aim of the Electric Club is to aid in the symmetrical development of Westinghouse men," yet was not specifically mentioned; that is, the value which flows from the experience the young man acquires in the management and direction of his own affairs.

The Electric Club is an organization composed of diverse dispositions and personalities. The attitude of the Electric Company has been merely that of continuous encouragement. Beyond that, the Club is a self-governing and practically self-supporting body. In operating and directing the activities of their Club, these young men are not only learning the lesson of democracy but of business organization as well. The value of doing things right and the evil of putting in force inadequate and incorrect judgments is brought home to them in a forcible and conclusive way; i. e., by the failure or success of their plans.

While it may be argued that this experience is trivial in itself, still it is of the utmost benefit to the man and to the Electric Company, as we must look to these men for our future foremen, engineers, salesmen and officers.

L. A. Osborne

Grounded Neutrals With Series Resistances

Mr. Ricker's discussion of the experience of the Interborough Rapid Transit Company of New York with the grounded neutral, in this issue of the Journal, is worthy of careful study. The question as to whether or not it is advisable to ground the neutral point of a high tension system has been a matter of controversy for a number of years.

Broadly speaking, the advantages of the grounded system are: The limitation of the rise of potential to earth that occurs when one line of a system is grounded, such a ground giving not only line potential between the other line and the earth but tending also, when sufficiently abrupt, to cause high frequency oscillations of the static potential (the maximum amount of such oscillation where no secondary effects occur is double line potential). And the causing of a short-circuit if one line wire becomes grounded, thus resulting in the opening of the circuit breaker at the grounded feeder.

The disadvantage of the grounded neutral system is the fact, as just stated, that a single ground is sufficient to cause a short-circuit and an interruption of the service on that line. In some systems where it is possible to operate with one wire grounded this causes unnecessary interruptions of the service, for it would at times be possible to locate and remove grounds without shutting down the load. Since there is nothing so important in a power system as uninterrupted service there is in such plants this decided reason for not grounding the neutral. Experience, however, has shown that in most plants, especially the larger high tension plants, it is impractical to run with one line wire grounded on account of the charging current between the earth and the ungrounded wires which must pass from the grounded wire through the generator to the other wires. This current is often large enough to either burn off the line wire at the point where the ground contact occurs or to destroy the insulation of a cable and cause a short-circuit to the other conductors in case of underground systems. Such a ground may cause unbalancing of aerial lines which will produce great disturbance in all telephone and telegraph systems paralleling the circuit.

It seems then that in certain cases the disadvantages of the grounded neutral far outweigh its advantages, the principal one of which is the prevention at comparatively rare intervals of an extra potential to ground or an oscillation. In many plants such grounds not only cause interruption of service on the grounded feeder which may be comparatively unimportant but also causes further breakdowns perhaps of important apparatus on other circuits and the shutting down of the whole system. It is evident, therefore, that in a distributing system such as that of the Interborough Rapid Transit Company where there are many feeders, any one of which is of comparatively small importance, if it is possible to so arrange the grounded neutral as to open the particular feeder which may happen to be grounded without shutting down the rest of the system, a very great advantage in practical operation will be obtained. By the use of the resistance in the ground wire of the neutral, as described by Mr. Ricker, this favorable condition has been approximately secured in the Interborough Rapid Transit Company's generating plants.

It must be remembered, however, that the series resistance, broadly speaking, tends to prevent the realization of the advantage of the grounded neutral since it hinders the free flow of current to earth. With a comparatively high series resistance the short-circuit troubles are limited and the circuit breakers open quietly but the current taken is not sufficient to prevent the rise of potential to ground on the rest of the system. As this resistance is made relatively less the short-circuit current becomes greater but the rise of potential is better controlled. In working out this problem it must be determined for each plant whether there is a compromise value of the resistance which will sufficiently secure both advantages. With six ohms and a thousand amperes, the values given by Mr. Ricker, the voltage on the resistance at time of a ground is practically full-load voltage showing that it is towards the maximum allowable value as regards protection against static disturbances. Practically what we have in this case is a shunt circuit taken from the neutral point of a generator through the grounded line which has its resistance so adjusted as to take sufficient current to open the feeder circuit breakers.

So far the discussion has applied strictly to one generator. The system becomes complicated when there are several generators in parallel. If a separate ground resistance is used with each generator the amount of short-circuit current will depend on the number of generators in parallel and will vary greatly. If a common neutral bus bar with a single resistance is used a switch must be provided between the neutral bus bar and each generator so that a generator may be disconnected from the neutral as well as the main bus bars, for otherwise an idle generator would receive potential from the other machines in the case of any disturbance. Furthermore, what is a much more serious factor, as Mr. Ricker has pointed out, there may be an interchange of current between the generators on account of the paralleling of the neutral connection. The compromise actually used in this case is the grounding of the neutral point of the generator which further reduces the effectiveness of the protection against the initial static rise accompanying a ground. However, since in this system at least some considerable time is probably required before difficulty results from a ground, as is shown by the static manifestations which have preceded trouble in the past, practical protection is secured, since a ground causes a practically instantaneous opening of the affected feeder circuit breaker.

It is evident that the grounding of the neutral in the Interborough Rapid Transit Company's lines has been most carefully worked out and in all probability the new arrangement will be of great assistance in obtaining absolutely uninterrupted service. It is probable also that a similar arrangement can be used in other plants, but since the effect depends largely upon the conditions at each plant this system should not be adopted without a careful consideration of all the conditions.

PERCY H. THOMAS

Notes and Comments

An eminent gentleman who spoke most appreciatively of Col. Prout's address, which appears in this issue, was requested to contribute his comment to this section of the JOURNAL. He dictated a page or two, and then found that he had really added nothing; he could not illuminate the subject further; a great theme had been most admirably handled and his own notes he assigned to the waste-basket. But possibly a word here may attract the attention of some who might otherwise pass over the address without discovering its worth. It is the mature thought of a man who is a scholar and a thinker, and whose experience as an engineer, soldier, editor and manager give his views exceptional weight. What he says appeals to all who are interested in the problems of progress, but especially to the engineer and to the engineering student and teacher. There are few to whom it will not bring new ideas and new ideals.

It is noteworthy that in the treatment of his broad subject Col. Prout devotes so much painstaking attention to education. Those who strive to upbuild an individual, a profession, an industry or a nation are pretty sure to come to the common conclusion that the fundamental thing is education. Two of the most significant facts in the engineering world are, the recent advance in engineering education in both its quantity and methods, and, the high value which is being placed upon this training. The demand increases even faster than the output of our engineering schools. Supplementing the technical schools, particularly in electrical lines, are the post-graduate or engineering apprenticeship courses of the large manufacturing companies. The coming together each year of two or three hundred young men representing nearly every engineering school in the country, alert and active, in contact with manufacturing and testing on a large commercial scale and with organized facilities for acquiring a knowledge of the construction and operation of apparatus with such additional opportunities as the Electric Club affords, probably contributes more to the training of American electrical engineers than any school of technology.

Aside from the advanced engineering courses, there is a field —in some ways a greater field—for education of a somewhat different kind. This is shown by the success of the correspondence schools. Such schools impart knowledge, but even a more important end is the training they give in the co-ordinate use of mind and hand. The average boy who leaves school and goes to work is apt to have had little but memory exercises. His schooling and his work seem to have little connection. The Casino Technical Night School has been developing in a quiet way until it has become an important educational force among the Westinghouse men at East Pittsburg. It has special and regular three-year courses, an enrollment of two hundred, a body of energetic teachers who come directly from their regular work in manufacturing, testing, draughting or engineering departments. Its methods are direct and effective. It may be questioned whether very many of our more pretentious laboratories have a more effective method of demonstrating the methods and characteristics of induction motor windings than that which has been devised for the Casino school and which is described in this issue.

The engineer, the designing engineer in particular, needs definite physical conceptions. Mathematical methods are inadequate unless they are accompanied by concrete ideas. A formula is usually a rather dangerous instrument if one does not really understand the law which it expresses. An admirable example of the application of a simple method of analysis, rather than a complicated formula, to several confusing problems is found in Mr. Lamme's article in this issue of the JOURNAL. It will bring satisfaction to many who have puzzled over the single-phase induction motor and it incidentally illustrates the method which this eminent engineer is apt to apply to the problems which come before him. CHAS. F. SCOTT

SOME PHENOMENA OF SINGLE-PHASE MAGNETIC FIELDS

B. G. LAMME

Chief Engineer, Westinghouse Electric and Manufacturing Company

WHEN a single-phase alternating current is present in rotating electric machines it generally gives rise to some very complex actions. In the case of magnetization by polyphase current it is well known that the shifting magnetic field thus set up may be looked upon as the equivalent mechanically rotating field excited by direct current and many of its actions can readily be illustrated in this manner. A single-phase magnetic field in itself, however, does not present any such idea of rotation, yet the results in many cases are such as would be found with a rotating field. This apparent rotating field action can be explained upon the assumption that the single-phase field can be resolved into two fields, each having half the maximum value of the single-phase field, these two fields rotating at uniform speed in opposite directions. Where these two fields coincide in position and direction, a field of double value is obtained. Where they coincide in position, but with opposite directions, a zero field is obtained. In this way the resultant of the two rotating fields of constant value will be equivalent to magnetic fields fixed in position but periodically alternating in direction, or is the equivalent of the field set up by fixed windings carrying a single-phase alternating current.

Several cases are given below, in which this method of analyzing the single-phase field will furnish a simple explanation of certain characteristics of single-phase machinery.

SINGLE-PHASE ALTERNATOR WITH SINGLE-PHASE FIELD EXCITATION

The suggestion has been made from time to time that direct current could be obtained from a single-phase generator by exciting its field by single-phase alternating current instead of by direct current. The reasons usually advanced for this are as follows:

If the field is excited by direct current, then when the machine is rotated the armature gives a single-phase alternating current of a frequency depending upon the number of poles and the speed of rotation. It is assumed, therefore, that if the polarity of the field is reversed at the same rate as the armature current alternates then every other alternation of the armature will be reversed, and the result will be a pulsating direct current. As such reversal of the field could be obtained by exciting the field coils with single-phase alternating current of suitable frequency it is assumed that by this simple means a machine giving a pulsating direct current of any desired voltage can readily be obtained. It is evident that such a method of obtaining direct current, if feasible, would have been used long ago, for the apparatus has no commutator and is relatively simple in construction. Evidently there is a fallacy in this reasoning. By resolving a single-phase exciting field into two oppositely rotating field it may be seen at once that instead of giving direct current such a machine will in reality give single-phase alternating current of double frequency.

Assume, for illustration, that the field structure of the machine is stationary and that the armature rotates. The alternating magnetic field set up by the single-phase exciting current can be considered as the resultant of two fields of constant value rotating in opposite directions. As the frequency of the exciting current is the same as that of the armature itself, one of these component fields will rotate at the same speed as the armature, and in the same direction, while the other field will rotate at the same speed but in the opposite direction. That field which is rotating with the armature will evidently have no effect in generating e.m.f. in the armature for there is no movement of the armature windings with respect to this field. However, the other field, rotating in the opposite direction, will have the same effect as if the field structure had been excited by direct current and rotated mechanically in the opposite direction from the armature rotation and at the same speed, or the effect would be the same as if the field had been held at a standstill and the armature rotated at double speed. The frequency thus obtained will be double the normal frequency of the armature.

SINGLE-PHASE INDUCTION MOTORS

A simple general explanation of the action of a single-phase induction motor may be obtained by the above method of analyzing the field, providing one understands the general characteristics of the corresponding polyphase motors.

Consider first the induction motor at standstill with single-phase current applied to its primary winding. Let the primary single-phase field be represented by two fields of half value rotating at equal speeds in opposite directions. It is evident that each of these fields would tend to develop torque in the armature if its circuits are closed, but these torques will be of equal value and in opposite directions. The motor should, therefore, have no tendency to start. If by external means the motor is speeded up in either direction it will be found that above a certain speed it will continue to run and will even accelerate to practically full speed if not too heavily loaded. The explanation of this action is comparatively simple on the basis of the two rotating fields. When the motor is speeded up in either direction its armature approaches the speed of one of the fields and departs further from the speed of the other field. Taking either field alone into account the motor may be considered as a polyphase motor in its action. It is well known that the torque of a polyphase motor, with low resistance secondary windings, increases from zero speed up until near full speed. Also, below zero speed; that is, if the secondary is rotated in the opposite direction from the field, the torque will decrease as it departs from the zero speed. Therefore as the armature speeds up in either direction it approaches the speed of one of the rotating fields and the torque due to this increases, while the torque due to the other field, from which it is departing in speed, decreases. The motor may, therefore, be considered as developing two opposing torques which are equal at zero speed but one of which is rising and the other is decreasing as the motor speeds up in either direction. The difference between these two opposing torques will, therefore, be the effective torque of the single-phase motor. The following diagram will illustrate this. In Fig. 1 is shown the speed torque curve of a polyphase motor from synchronous speed to zero and also to 100 per cent below zero. In this case the resistance of the armature is assumed to be relatively small and the torque at the zero position is considerably less than the maximum torque which the motor can de-

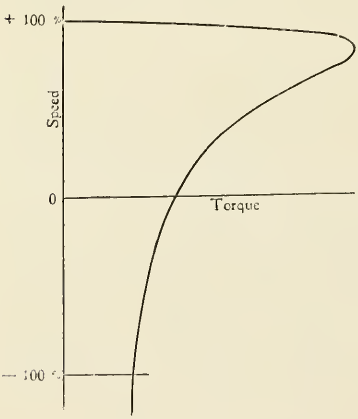

FIG I

velop. The torque at 100 per cent below zero will, therefore, be considerably lower than at the zero position. This figure will illustrate the speed torque curve due to one of the component fields of the single-phase motor.

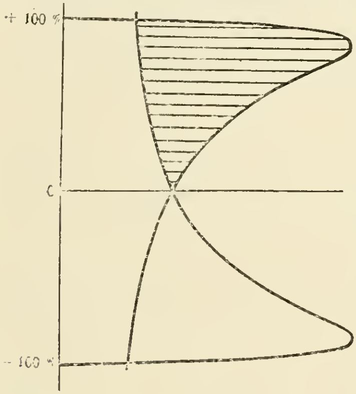

FIG. 2

In Fig. 2 the speed torque curve of Fig. 1 is shown and also the corresponding speed torque curve due to the other component rotating field. The speed torque curve of the second field should have the same form and values as that of the first field but rising in the opposite direction; that is, increasing below the zero line. The resultant torque charistics of the motor can therefore be represented by the difference between these two torque curves at any given speed. The resultant torque at zero speed is zero, and it rises when the motor is started in either direction. This method of analyzing the motor also explains an interesting characteristic of the single-phase motor in which it differs from the polyphase motor. It is well known that the maximum torque of a given polyphase motor is independent of the resistance of the secondary circuit, the maximum torque being the same for all resistances but the point of maximum torque occurring at a higher or lower speed as the resistance is decreased or increased. This is illustrated in Fig. 3, in which a number of torque curves are shown with different resistances. In the single-phase motor, however, the maximum torque is not independent of the secondary resistance but will decrease when the resistance of the secondary is increased. This is shown very plainly if the speed torque characteristics shown in Fig. 2 are applied to the curves of Fig. 3. This

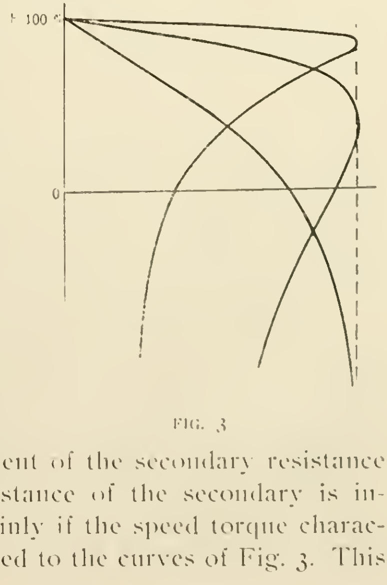

FIG. 3

is shown in Fig. 4. An examination of this figure shows very clearly that the difference between the two opposing torques will depend upon the shape of the component polyphase speed torque curve as well as upon its maximum value. A higher resistance in the secondary does not increase the maximum torque that one of the fields can give, but does increase the opposing torque which the other field can give, and therefore the resultant torque will be reduced.

This method of analyzing the characteristics of the single-phase motor shows in a general way why the torque and output when operated single-phase should be so much less than when operated on polyphase circuits. The torque of the single-phase motor is due to the difference between the torques of the component polyphase torque curves and each of these component polyphase curves is evidently of much lower value than would be obtained in the same motor when operated as a true polyphase machine.

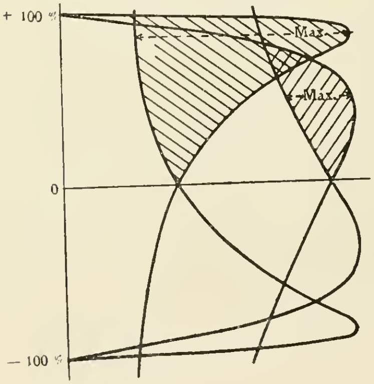

FIG 4

POLYPHASE MOTORS WITH SINGLE-PHASE SECONDARIES

If a polyphase motor with wound secondary and collector rings is run with one or more of its secondary circuits open so that but a single circuit or path is closed, it will be found that such a motor will operate at approximately one-half speed and develop considerable torque. With increase in torque the speed falls off as in the case of a normal polyphase motor at full speed. A rough explanation of this action is found in the method of resolving the single-phase field into two oppositely rotating fields.

When the secondary, with but a single circuit closed, is rotated at half speed it generates current at half the frequency of the primary circuit. This single-phase secondary current sets up a single-phase field of half the primary frequency and this can be resolved into two opposing rotating fields. As the armature is traveling at half the speed of the primary field, and as the frequency of the secondary current is half that of the primary, it is evident that one of the secondary fields has therefore a resultant speed equal to that of the primary field and in the same direction.

The other secondary field will have a resultant speed which is zero and is therefore stationary with respect to the primary windings and can have no effect upon them. The conditions at half speed are therefore equivalent to those of the ordinary polyphase motor at synchronous speed. This should, therefore, be a position of zero torque and the motor should have no tendency to rise above it. If the motor is now loaded it will tend to fall off in speed like the polyphase motor and will develop considerable torque up to some maximum. If loaded beyond this it will fall off in speed like the polyphase motor. This motor, therefore, runs at half speed or lower, practically the same as the ordinary polyphase motor runs at full speed and below. However, the primary circuits take very heavy currents under these conditions of half speed and the motor has a very poor power-factor. This method of reducing the speed of a polyphase motor is, therefore, not an economical one.

The above explanation of the action of a polyphase motor with single-phase secondary is incomplete, as it does not give a clear view of all the actions. At exactly half speed one of the fields, as stated above, is at a standstill with respect to the primary windings. As the motor slows down under load this field is moving with respect to the primary windings and is evidently generating e.m.f.'s in them at a frequency which is increasing as the motor slows down, and the interaction of this field upon the primary circuits may give rise to some very complex conditions.

Another case where a similar half-speed action in polyphase machinery is found is where polyphase rotary converters or synchronous motors are started by applying current to the armature terminals. In some instances it is found that a machine will start readily but will tend to lock at half speed. In such cases of locking it will generally be found that the field structure, and the secondary circuits on the field, are arranged so as to give a relatively good single-phase action and the motor thus tends to run at half synchronism just as in the above case of an induction motor.

There are a number of other phenomena of single-phase fields which can be explained on the above assumption of oppositely rotating fields. However, the examples given will serve to illustrate this method of analyzing such problems.

SOME RELATIONS OF THE ENGINEER TO SOCIETY*

H. G. PROUT, A. M., C. E.

IN the summer of 1903 an eminent engineer died in New York, Mr. George Shattuck Morison. He was a man of broad education and of a powerful mind and illustrious achievement. Like most engineers he wrote but little, but he left behind him a manuscript which was afterwards printed in a book of one hundred and thirty pages, under the title of "The New Epoch as Developed by the Manufacture of Power". You can read it easily in two hours, but it sums up much of the reading and meditation of a vigorous and intellectual life.

Mr. Morison reminds us that students have recognized certain great ethnical epochs in the progress of mankind. The use of fire first lifted man out of the condition of the animals around him; then came the use of the bow and arrow which further established his superiority. The next great step was the use of pottery, and man passed from savagery to barbarism. The domestication of animals and the manufacture of iron marked two more eras in the development of the race. Finally came the use of the written alphabet, the greatest and most useful of all human inventions, by which knowledge could be preserved and distributed. Progress thus became continuous and great masses of mankind were enabled to advance simultaneously along the same lines. This was the step from barbarism to civilization, and there the ethnical periods are considered to have closed. What has followed is assumed to be but the natural advance of civilization. But Mr. Morison thinks that there is no apparent reason why other epochs should not come, just as distinct and just as important as either of the six which are behind us. It but needed the discovery or the development of a new capacity to make a new epoch, and such a new capacity came with the manufacture of power. By the development of the manufacture of power man's capacity is suddenly increased beyond any limit which the human mind can forsee or imagine. The strength of man or the strength of animals no longer sets a boundary to the capacity to do work. Forms of matter are changed, and the forces of nature are set to do our bidding, and we can see no stopping place in this process. The power of man to do useful work has been multiplied in the last century beyond all computation or imagining. In the last one hundred years man's productive capacity has probably advanced more than in all the preceding years that he had inhabited this planet, and the revolution wrought by the development of the capacity to manufacture power has just begun; the door has just opened.

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* An address delivered at New Haven in the Sheffield Lecture Course, February, 1905; at Wilkinsburg before The Electric Club, November, 1905; at Ithaca at the First Annual Reunion of Civil Engineering Alumni of Cornell University, June, 1905.

I think it was Mr. John R. Freeman who estimated that in one voyage across the Atlantic a steamship developes as much power as was developed by hundreds of thousands of men working through decades of time to build the great pyramid; but the biggest ocean ship is small compared with the great power factories which we can see all around us, and this power is delivered in our houses and in our shops and on our railroad tracks, to the immense saving of time and energy. It would interest you to try to compute the human effort saved by the mere fact that some hundreds of thousands of maids and housewives draw water from spigots, where it is delivered from steam pumps, instead of going to wells. How can we measure the effect on human society of the fact that two men in a locomotive cab haul two thousand tons of goods or five hundred passengers across half a continent at forty miles an hour, or of the fact that every steam hammer in a forge shop does the work of a dozen men, and does it better?

While the capacity of man to do accustomed things has been multiplied, he has been empowered to do things that he could not have done before. The steel forgings that are made now could not have been made at all by man-power or animal-power. Manufactured power was necessary to the production of the great structures of to-day—the ships, the guns, the bridges, the great engines in the power houses, the tall buildings in the cities. Perhaps there are those now before me who doubt if human happiness has been increased by the mere capacity to produce big things. You will remember Ruskin's ideal society, with the happy peasant in a velvet jacket singing in the fields, the heavens unpolluted by the smoke of mills and the air unvexed by the noise of railroads. Not long ago a professor in a neighboring great university maintained with some heat, the superiority of the Greek civilization, when the mass of the people lived in squalor and built Parthenons, as compared with our civilization when the mass of the people are more sure of food and clothes and fuel, and build ugly steel frame Masonic Temples. We cannot stop here to discuss the relative value of civilizations, but I make bold to believe that the average of human happiness was never so high as now.

The examples which I have cited only suggest the amount of human effort that has been set free by the manufacture of power. My imagination is unequal to the task of giving you more than a hint of the change in man's condition which has just begun, and even to-day the manufacture of power, an art a little more than a century old, is in process of revolution. The prime mover of yesterday will not be the prime mover of to-morrow. Our methods of using the stored heat energy of the sun to-day will be history twenty-five years from now.

It is less than one hundred and fifty years since Watt made the reciprocating steam engine a thing of actual use, and fairly began the era of manufactured power. Already the reciprocating steam engine is doomed, except for certain special uses. The development of the transmission of power by electricity has made it possible to use the high efficiency of the steam turbine, and the use of turbo-generators is even now large and spreading fast. But the turbine is only a step. Its successor is already foreshadowed in the gas engine. Side by side with these changes in the type of prime mover advances the art of transmitting and using power by electricity and so swiftly does the art advance that now the day seems close at hand when we may see short but important lines of steam railroad of heavy traffic converted to electric working. The power houses will be equipped with steam turbines or with gas engines. Alternating current will be sent out over long transmission lines and stepped down and used in the car motors without converting. Two great things will be accomplished. Working cost will be reduced and the public will have more frequent, cheaper and perhaps swifter service.

These are a few of the great engineering changes now visible over the horizon. If we had time we might speak of others in the fields of transportation, of sanitation and of manufacture, which will possibly have even more effect on the wealth and happiness of man than those which I have mentioned. For instance, who can foresee the effect of countless small improvements in manufacture which are flowing from the swift development of mechanical, electrical and chemical knowledge and skill? And perhaps even greater results will flow from improved sanitation saving present waste of human energy. And these changes are close at hand.

We may reasonably suppose that twenty-five years from now, when many of the young men now sitting before me are in the full tide of their useful work, these United States will have a population of one hundred and twenty million. That will be more than the present population of the United Kingdom and France and half of Germany combined. It will be a free and homogeneous population, more efficiently educated than any people the world has ever seen. It will be a population of singular daring and enterprise, this for two great reasons. For ten generations the Americans have lived under conditions to develop courage and enterprise; and the immigrants coming to our shores must be, generally speaking, class for class, more courageous and enterprising than those whom they have left behind or they would not have come. This population, so vast in numbers, so efficiently educated, so courageous and enterprising and so free to work, each man in his own way, will be seated in a temperate climate, amongst unrivalled resources of soil and mine, in a country intersected by great natural waterways and covered with a net work of railroads and with a vast coast line on the two great oceans. Put into the hands of such a people, so situated, the means for the manufacture of power and their influence on the world, physical, intellectual and moral, may be greater than the influence of the men who built the Roman Empire, greater than the influence up to this time of the race which built the empire of the English-speaking people. What a glorious thing it is to be a young American at the dawn of the new epoch!

These matters of which I have just been speaking are important. They are occupying much of the best intelligence of the world. They are pursued with most admirable enthusiasm and devotion. But regarded in a broader way they are only incidents in the general forward movement of the new epoch. Not only have we entered on another ethnical period, but upon the most important period in the progress of mankind. It is quite conceivable that a thousand years from now men may look back to the 19th and 20th centuries as the most significant period in the history of the race.

Perhaps you begin to wonder where I am coming out, perhaps you are already asking what all this has to do with the announced subject of my lecture—"Some Relations of the Engineer to Society".

My proposition is that the engineer, more than all other men, has created this new epoch and that the engineer, more than all other men, will guide humanity forward until we come to some other period of a different kind. On the engineer and on those who are making engineers rests a responsibility such as men have never before been called upon to face; for it is a peculiarity of this new epoch that we are conscious of it, that we know what we are doing, which was not true in either of the six preceding epochs, and we have upon us the responsibility of conscious knowledge.

If we are right in the notion that the manufacture of power has brought mankind into a new ethnical period; if we are right in the notion that the engineer is the man who beyond all other men has created the new conditions and who must beyond all other men carry them forward in their development, then we are face to face with certain facts of tremendous importance to two classes of our fellow citizens: First, to those who are responsible for the training of youth for their work in the world; and, second, to those young men who have chosen engineering as their profession.

The same events and conditions which have created the new epoch have affected the plans of education, and, so far as I am qualified to judge, those who are training the young men who are to guide the human race in the next few decades are working forward in the right direction. It is obvious that our aim must always be to acquire a more complete and perfect knowledge of the forces of nature and to this end we must have mathematics. Years ago Prof. Bartlett, in the introduction to one of his remarkable books, said that the man who is endowed with the priceless boon of a copious mathematics possesses the key to the external universe. It is my observation of a good many young men starting as engineers that their mathematical training is defective. Instead of holding a key they have a feeble grasp on something as vague as fog; they have not been trained to use their mathematics as a tool for investigation, or for analysis, or for conclusive reasoning. Perhaps we may attribute this partly to the survival down to this day of Plato's notion that geometry is degraded by being applied to any purposes of vulgar utility.

Close to this is physics. A command of those facts and laws which we roughly group under the head of physics is more important than a command of mathematics. A mere mathematician cannot be an engineer, but a man can be an engineer with limited mathematics if he has a working conception of the laws of physics. My favorite test of the intellectual power of a boy is to ask how he stands in physics. A high stand there is a pretty certain indication of imagination, of power to analyze and of capacity to reason.

Command of the forces of nature requires besides mathematics and physics a specific knowledge of those branches of learning which we call the natural sciences. The relative importance of any one of these to any one man must depend upon the kind of work which he intends to do, but some knowledge of almost all of the natural sciences is important to the engineer, and a large and definite knowledge of some of them is necessary.

But mathematics and physics and the natural sciences are not the end. If an engineer is to go far he must have some of those studies which give him broad and just ideas of the relations of man to man and of man to society.

The duties of my life bring me into daily contact with large industrial and commercial interests employing many men, and I say in all sincerity, and with due regard to the meaning of my words, that it is far easier to hire engineers than it is to hire men.

It is my constant observation of four engineering works, employing about 20 000 men, that engineers reach the limit of their usefulness from defects of character, rather than from want of technical attainments. Our greatest difficulty is to find courage, candor, imagination, large vision and high ambition. I do not know which of these qualities is most often lacking, or which is most essential. The lack of courage and candor comes most often to my notice, but the lack of imagination and of broad outlook produces the most serious disasters. All of these things an engineer must have if he is to go far, and all of these any citizen must have if he is to go far in the work of life. Our scheme of education will be radically defective if it does not provide for the development of courage and candor, of imagination and broad vision and high ambition. Our scheme of education of the engineer and the citizen must also teach our youth something of the large mistakes of men and nations in the past and something of their successes. Lacking that teaching we see the farmer in Texas and the third rate lawyer in Congress and the professional friend of mankind in Nebraska re-inventing ancient errors and diverting valuable energy from the useful purpose of hoeing corn. It is not for me, not even an amateur in education, to say how these things should be reached, but I venture a suggestion.

Scientific study may be in itself a great expander of the imagination. You will remember that Prof. Shaler wrote five dramas in blank verse to prove this. I am not competent to judge of his demonstration, but at least I venture the assertion that the study of chemistry or of biology, of machine design or of analytical geometry, of geology and astronomy, is as quickening to the imagination as the study of Greek or Latin grammar, of moral philosophy or of rhetoric, or as a formal and routine study of English literature. The result is mostly dependent on the teacher and not on the thing taught. The quickening influence is the human influence.

This brings me to another suggestion. Gordon used to say that it would be better if the young British officers were made to read Plutarch's Lives. "There we see men of no true belief, men who are pure pagans making their lives a sacrifice as a matter of course. In our day it is highest merit not to run away." This is a fertile suggestion under which lies a truth of the greatest importance in the scheme of education. At this moment we may see Plutarch's men fighting for their country on the other side of the world and showing noble devotion and a lofty idealism, because for centuries and centuries great ideals have been held always before them. Admiral Togo's little address to the spirits of the dead the other day in Tokio was a noble inspiration to the youth of his nation. It had the very spirit which made Plutarch's men immortal. The essential thing is to bring youth into habitual and constant contact with great men and great ideas and great deeds. Make them read Huxley's Life and Letters and Lord Robert's Forty-one Years in India and Grant's Memoirs. Or, perhaps better than any of these, let them read deeply in the story of Lincoln's life. There they will find the simple foundation qualities, love of truth, courage, patience and fortitude, tenacity and devotion, working in great fields of effort. If these examples do not stir a young man, you had better let him go quietly back to hoeing corn. He may make a useful man and a necessary man, but he cannot make a great man or even a big man. Huxley has said that the progress of mankind has been through the production of men of genius; but society cannot deliberately and consciously produce men of genius. They are the rare fruit of a thousand uncontrollable conditions, but we can deliberately and consciously develop leaders, and the affairs of men have never called for leaders so loudly as now.

I said a while ago that we are face to face with certain facts of tremendous importance to those who are training young men for engineering, and to those who have chosen engineering as their profession. I have suggested a few considerations, more particularly for those who are educating the young engineer, and now let us turn to the engineer himself.

It is my proposition that the engineer more than any other man has brought about the new epoch which we have now entered upon and that he more than any other man is to lead mankind forward in the next century or two. But who is this engineer to whom we assign such a place in human progress? What is engineering? These claims, so broad as to seem extravagant, must rest on a broad foundation.

You will have observed that of the six great forward steps taken by the human race as a race, five were enlargement of his physical powers and improvement in his material welfare, through conquests over the forces of nature, and the sixth of these great steps worked for his advancement by enabling him to preserve and distribute knowledge. Even that step probably had its greatest value in hastening the conquest of nature. So we must not be surprised to discover that progress is through knowledge of a material universe.

Some eighty years ago Tredgold made that famous definition of engineering which has never been improved upon. It is the art of directing the great sources of power in nature to the use and convenience of man. Broadly this definition must include the physicist, the chemist, the biologist, the geologist and the metallurgist, for they discover those laws and properties of matter in the knowledge of which the engineer must work. Narrowly the engineer is one who, having knowledge of the laws and properties of matter, designs and constructs. The primitive engineer, the man who had that instinctive feeling for the forces of nature and for the properties of matter, and that quality of contrivance which must be born in a man if he is to be an engineer at all, taught his fellow savages to use fire, to use bows and arrows and to make pottery. Then he taught his fellow barbarians to use the strength of the larger animals and to smelt and forge iron. Just so the modern engineer using the same heaven-sent qualities is carrying forward the conquest of nature until he has brought us into this last and greatest era, the era of the manufacture of power.

I shall not stop to name his doings, they are written across the face of the earth. You remember what Carlyle says of the English, "Of all nations the English are the stupidest in speech, the wisest in action. Thy epic, unsung in words is written in huge characters on the face of this planet—Sea-moles, railways, fleets and cities, Indian Empires, Americas, legible throughout the solar system, England her mark." Such, too, is the epic of the engineer written in railways, canals and bridges, in fleets and harbors, in water works, roads and parks, and finally in the great ultimate struggles of mankind on the battle field to save and destroy nations. There, too, the engineer writes his tragic poetry. You never thought of him as a poet, did you, and yet in the last one hundred years the highest expressions of the creative imagination have been in the work of the engineer.

A few years ago Mr. Abram S. Hewitt said that Sir Henry Bessemer had done more than any other man of his time to destroy the power of the privileged classes in Great Britain, that he was the great apostle of democracy. Bessemer's service to mankind was to lower the cost and increase the quantity of steel and so make possible the enormous development of transportation in the last half of the last century, which has changed the face of society, and I do not believe Mr. Hewitt over-estimated the importance of Sir Henry Bessemer's achievement. The wheat that makes a loaf of bread is carried from Dakota to New York for one-third of a cent. One day's wages of a mechanic will carry from Chicago to Liverpool food to last him a year. Quick transportation has cut the peasant loose from the soil of his little parish and opened the markets of the whole world for the labor of the artisan. All this means that improvement in transportation has been one of the powerful forces for preserving and spreading liberty. Thus Bessemer was the apostle of democracy. The engineer has made life freer and easier, he has helped to destroy arbitrary class distinctions, and he has prolonged human life.

I shall not dwell longer on what the engineer has done. I wish especially to take a little time to point out some of the things which he is about to do. Bear in mind that in what I shall say I use the term "engineer" in its broadest sense to indicate the man of modern scientific education and of practical contrivance. Trained in daily contact with exact and inexorable laws he is becoming more and more a leader in large affairs, he is fast taking his place at the head, and close to the head, of the great industrial concerns. Mind I do not say that he will displace men of other professions. Men bred to the law, men trained in business, will always rise to the top. Superior men will make their way to command through many different avenues. What I do mean to say is that the education and experience of an engineer especially fit him for high administrative positions not now commonly thought of as engineering work. Carlyle tells us that "Frederick the Great's ambassadors are oftenest soldiers. Bred soldiers, he finds, if they happen to have natural intelligence, are the fittest for all kinds of work." In Frederick's time engineering as a profession did not exist. Soldiering came nearest to it, and there is great likeness in the work of the engineer and the soldier and in the qualities of mind and character developed in the two callings. Both must ascertain physical facts without mistake. Both must analyze and weigh evidence and must reason correctly. Both must deal with relations of time, space, force and matter. Both must handle men in action. Both must have the restrained and disciplined imagination to project clearly conditions and results which they cannot see. Both must decide, often very quickly, knowing that on the decision hangs success or failure. But this is the training which makes men of action—leaders, commanders. No doubt you will agree with much that I have just said, but I question if you will quite appreciate the gravity of the sudden emergency work which comes in an engineer's life. Suppose you are putting down a deep foundation alongside of a twelve story building in New York City and the quicksand begins to run and the walls of the big building to crack. The peril is not so pressing as the peril of battle for you can stop work and think. But you must think straight and act right or you will cost someone a lot of money, even if you kill no one. Suppose you are putting in a foundation for a bridge pier in the bottom of the Mississippi and the river bed begins to scour and a caisson as big as a house begins to tip and to move down stream. A great deal of money depends on what you do in the next few hours. Suppose you are putting a tunnel under the St. Clair river and the compressed air begins to blow out through a pocket in the river bed. Here is an affair of minutes, and of life as well as money. These very things have happened and are exactly the things that come as a matter of course in an engineer's life, and they are met by just the same qualities of courage and stored up skill and emergency judgment that you must have ready when the enemy gets on your flank. Beyond all this the engineer is of necessity a student of costs and economics. He must know what it costs to move a yard of earth and to put in a yard of concrete and why. He must know what it costs to produce a horse power. He has been defined as a man who can do well for a dollar what any man can do somehow for ten dollars. Beneath all this must lie sleepless fidelity to his trust.

These are some of the qualities of leadership, obvious, and recognized as produced in the contest with nature; but there are others, higher ones, not so obvious. I mean the qualities of moral leadership. Probably you never thought of the engineer as a moral leader and yet I have often thought and said that in a knotty case of applied morals I would sooner trust an engineer than any other man. I once said this to that famous moralist, the late Speaker Reed. It was apparently a new thought to him. He reflected as much as a quarter of a minute, which was a long time for him. "Yes," he said, "I guess you are right, a minister has no sense of proportion in sin." That thought is a little too delicate and complicated for me to follow further, but the lawyer is fair game. You will remember the saying of Macaulay on this matter. "We will not at present inquire whether it be right that a man should, with a wig on his head, and a band around his neck, do for a guinea what, without these appendages, he would think it wicked and infamous to do for an empire; whether it be right that, not merely believing but knowing a statement to be true, he should do all that can be done by sophistry, by rhetoric, by solemn asservation, by indignant exclamation, by gesture, by play of features, by terrifying one honest witness, by perplexing another, to cause a jury to think that statement false. It is not necessary on the present occasion to decide these questions." Nor is it necessary for us here to decide a question which every law student has debated over and again. For my present purpose it is enough to say that the daily practice of a profession concerning which such questions can arise puts a man of weak mind or weak character in very considerable peril of becoming a skillful sophist and a weak moralist. Even in the daily walks of business there is frequent temptation to obscure the truth. But the man who passes his life in contests with nature is not apt to be a sophist. The engineer can have no object in concealing the truth or in misusing it. His work is a material fact; it is not an impression upon the minds of other men. No trick of words, no art of speech, will make his bridge stand up, or his bearings run cool. No ingenuity of argument, no power of rhetoric will save one ounce of coal per horsepower-hour. We all know in some vague and abstract way that we must yoke our wagon to a star, but the engineer must do it. The law which guides him is not the product of the schools and the courts, it is not the product of changing standards of life and thought; it is the eternal law of nature. So far as he finds it and follows it he succeeds; so far as he misses it he fails, and there is no escape for him. Nature always stands watching him, neither kind nor cruel, but perfectly just—swift, inexorable, and inevitable—at once his guide and his judge. Who else of all mankind has a discipline so fine? Reward is so prompt, punishment is so swift and sure. Emerson has said—"The mind that is parallel with the laws of Nature will be strong with their strength."

I have pointed out some of the special and peculiar qualifications of the engineer for leadership. There is another which he enjoys in common with other professions. I mean that which we may call the professional spirit. It often seems to me that some of the great dangers to the social order which we see around us will be lessened, not cured but lessened, by the growth of the influence of the professional man in affairs. We are worried about the growth of corporate power. I don't believe that corporations are worse managed than they used to be, but they are bigger and stronger and we hear more about them, as we hear more about most things. However all that may be, we shall not change human nature by law, and corporate nature is human nature. I see much good to come from the growth of the professional spirit in corporate management. The professional spirit is in its essence the sense of trusteeship. When the professional man takes in trust the affairs of his client that trust becomes more binding upon him than his own personal interests. I am often amazed when I think of the vital force of this professional spirit of trusteeship. I am often astonished when I think of the great number of very common-place men who work along year by year with sustained devotion to a true standard of professional duty. It confirms my faith in the notion that the mass of mankind like to do their duty if they can only know what it is, and that the mass of mankind desire the approbation of noble minds. It is my impression that the true professional spirit is at least as strong amongst engineers as in any other profession, and I am often tempted to think that it is stronger. Here then we see still another reason to look forward to the leadership of the engineer.

Those of you who have been dozing or wandering while I have talked and who have caught only the high spots will have got the impression that I have been claiming the earth and the fulness thereof for a small group of our fellowmen who have chanced to band themselves in a certain profession. My real purpose has been to call attention to the commanding importance in the advancement of mankind of a certain sort of training, and I had hoped that the presentation of this thought, while not at all novel or original, might have a certain interest to you, gathered in the shadow of this noble university, and especially to the young men.

I have said that the engineer brought about this seventh epoch in the progress of the human race, the era of manufactured power, but I am not sure but we should go back three hundred years to Lord Bacon. It was Bacon's purpose to teach man to gain command over nature and he taught that this could be only by diligently learning the truth and then following it. And this is the real significance of the engineer as an ethnical force; he must know the truth and live by it. Bacon was not the first man to observe natural facts correctly and to reason from them simply and boldly. The savage engineer who taught his fellows to make fire must have done that. But Bacon roused great numbers of men to the dignity and value of natural knowledge. And I would ask you to remember, and especially the young men, that knowledge of man and his deeds and motives is a branch of natural knowledge. If we are to help mankind forward in this new era on which we have entered we must gain positive knowledge, and we must vitalize it by contact with great characters and great events. We must get command of the sources of power in nature and then within ourselves, we must have courage and candor, fortitude, tenacity and imagination, and devotion; and the greatest quality of all is devotion.

EXPERIENCE WITH GROUNDED NEUTRAL IN A HIGH TENSION PLANT

C. W. RICKER

Electrical Superintendent, Power Stations, Interborough Rapid Transit Company

THE Interborough Rapid Transit Company of New York operates two steam power stations in parallel, containing seventeen engine-driven and one turbine-driven, 10 000 volt, 25 cycle generators of 90 500 kw aggregate rated capacity; and seventeen sub-stations, containing eighty-four 1 500 kw rotary converters, aggregating 126 000 kw. There is a separate lighting system in the subway supplied by three 1250 kw, 11 000 volt, 60 cycle, turbine driven generators.

The capacity rating is very conservative, all the generators and rotaries being able to carry double load for considerable periods without injury. The sustained short-circuit current of the generators is about three times the full-load current, and that of the rotaries, running as alternating-current generators, in virtue of their stored energy of rotation, is, for a brief period, even greater. The momentary current to a ground or short-circuit may be much greater, depending upon the phase of the e.m.f. wave at the instant. The possible momentary flow of energy to any point in the high tension system, at which the insulation between conductors is broken down, is enormous, and although both generator and feeder oil switches are controlled by relays that are virtually instantaneous in operation on short-circuits, the switch mechanisms have a measurable time element which may be several tenths of a second, so that great damage may be done by a short-circuit.

The high tension distributing system consists of eighty-eight 25 cycle, 10 000 volt feeders, containing 308 miles of No. 000 and 13 miles of No. 0 000 cable, all operated in multiple, and three 60 cycle, 11 000 volt, lighting feeders, containing 22.3 miles of No. 6 cable. All of the feeders are three-conductor, paper-insulated, lead-covered, underground cable, except one and one-half miles of three-conductor, No. 000, rubber-insulated, lead-covered, steel-armored, submarine cable. The longest feeders are about 8.6 miles long, and the average length is 3.8 miles.

With all of the high tension generating, distributing and transforming apparatus and conductors insulated from ground, a breakdown of the insulation of a single conductor does not at once allow enough current to flow to operate the relays and trip out the switches through which the damaged conductor is fed, but a flow or discharge occurs at the fault, great enough to destroy very rapidly the insulation between conductors in the immediate neighborhood and cause a violent short-circuit. When this happens in a feeder cable, a portion of the cable is at once completely destroyed leaving an air gap of several inches or even several feet between the burned ends. If such a short-circuit occurs in a manhole where other cables are exposed to the arc, they may be seriously burned, even so badly as to short-circuit in themselves, and so spread the damage until a number of feeders are interrupted. All cables in manholes are protected by wrappings of asbestos and steel ribbon, but the amount of energy that can be concentrated at any point in the distributing system by a short-circuit is quite sufficient to destroy all the cable that can be put into a single manhole in an almost indefinitely short time, and leave no trace either of cable or protective wrapping. The damage which can be produced or rather provoked, by such an unconfined arc lasting a quarter of a second is not limited to its immediate vicinity. The arc, acting as a vibrator, gives rise to potential surges capable of weakening or breaking down the insulation in other and distant parts of the system, the effect of which may be apparent at once or only after several hours or days. Under such circumstances, one breakdown is usually accompanied or followed by others.

For instance: A three-conductor, No. 000, 10 000 volt, Subway division feeder cable, short-circuited at a joint where the insulation between conductors was insufficient. At the same instant a feeder oil switch in the Manhattan division power station (about five miles distant along the cables) was short-circuited and grounded on all three phases and badly damaged. The overload relays tripped the generator switches and shut down the power station. This particular switch had been in service for several years. It had been overhauled and cleaned within a few days, and was known to be in thoroughly good condition. At the same time the insulation of the potential transformer leads in one of the sub-stations was punctured, but the result was no more serious than the inconvenience of having to run the sub-station for some hours without any potential indicators or wattmeters and without synchroscopes in the primary side of the transformers which supply the rotary converters. This instance is cited because it is typical, although more serious breakdowns have occurred. The accidental momentary grounding of a high tension conductor will produce effects similar to those described, although not necessarily of the same degree. Such a ground is liable to strain the insulation at some part of the system so that a break-down may be expected shortly afterward.

Another very troublesome difficulty is added, in such a completely insulated system, when a feeder cable breaks down anywhere in the conduit line outside the power stations and sub-stations. As just described, all three conductors and the lead sheath are almost invariably burned up or melted, leaving a gap in the cable and a considerable and altogether uncertain resistance across the carbonized insulation between the conductors and the sheath. No determination of the position of the break can be made from either end of the cable, and after many trials extending over a period of years, the most satisfactory method of locating a fault was found to consist in sending from the power station, through the conductors and the lead sheath in series and across the insulation at the fault, a continuous constat current (from an arc dynamo). This current is reversed at short intervals, and can be traced by a galvanometer or a listening coil carried by an observer and placed near the exposed portions of the cable in the manholes. See Fig. 1. By this means the observer can distinguish the direction to the break, but in the case of a long cable, it may involve the opening of a great many manholes with hours of hard labor and weary searching, especially if the resistance at the fault is high and variable or if the fault is submerged in water, thus making the reversals indistinct. A short-circuit at a joint, when the sleeve is not wholly destroyed and still holds some compound which is melted by the testing current and heals up the break-down between the conductors and the sheath, is exasperating. The average feeder passes through about fifty manholes and the longest through more than one hundred.

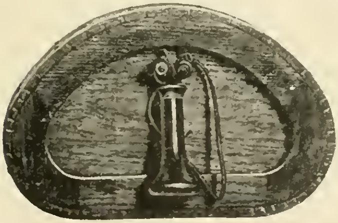
FIG. 1—LISTENING COIL AND TELEPHONE RECEIVER USED IN LOCATING CABLE FAULTS BY THE ARC DYNAMO METHOD

All conducting parts of the high tension generating and distributing system are more or less enclosed in grounded envelopes, which, except in the case of the three-conductor feeder cables and the transformers, include only single conductors. Even in the feeders and transformers the insulation from ground is less than between conductors.

To facilitate the arc-dynamo method of locating faults, which must still be used in case a feeder short-circuits and has two or three conductors burned in two, the lead sheaths of all cables are grounded in the generating stations and are bonded together in all manholes by lead straps with wiped joints. Outside of the generating stations, the lead sheaths are kept as free from grounds as possible

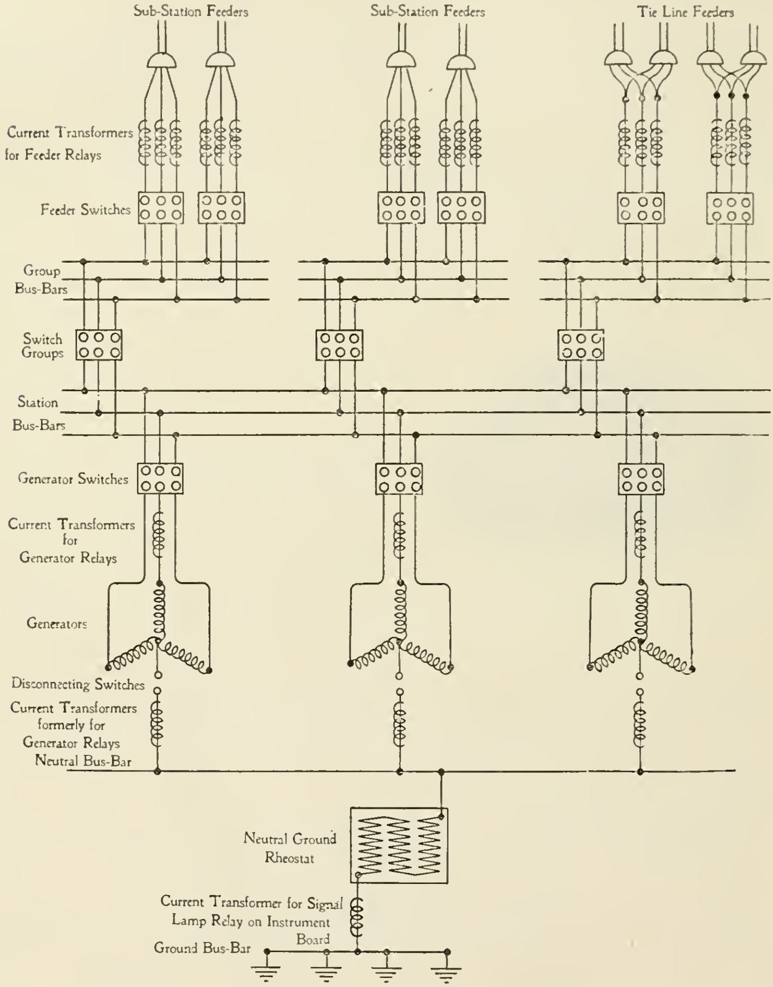

FIG. 2—SCHEME OF CONNECTIONS IN EACH GENERATING STATION. SIMPLIFIED DIAGRAM SHOWING THREE GENERATORS

and are practically insulated, except where they lie in very wet ducts. Bonding the cable sheaths together divides the return testing current so that it does not neutralize the effect upon the listening coil or galvanometer, of the current in the conductor within. This arrangement is also of material use in minimizing the effects of electrolytic action.

In order to prevent, as far as possible, the formation of short-circuits, it was determined to ground the neutral points of all the generature armatures, which are star-connected. The scheme of connections in each generating station is shown in Fig. 2. By interposing a resistance in the lead to ground, the ground current at a fault in the insulation of any single conductor can be controlled, or at least damped, so as to allow a maximum flow great enough to open the automatic oil switch in the grounded conductor, but not enough to do serious damage. This arrangement constitutes a complete protection against damage proceeding from breakdowns between single conductors and ground , though none at all against those occurring directly between conductors. As breakdowns to ground appear to be much more numerous, this partial protection is of great value and has been effective in every breakdown since its adoption, except one which was a short-circuit between conductors. In the generators, each phase of the winding is carried clear around the armature, so that the central point of the star is axially opposite the main leads on the opposite side of the armature. A lead is taken off at this point and conected, through a lever disconnecting switch and a current transformer, to an insulated bus-bar running along the station past all of the generators. Near the middle, this neutral bus-bar is grounded through a rheostat of six ohms resistance. See Fig. 3. The ground lead passes through a current transformer and is connected at several places to the discharge piping of the steam condenser.

The neutral ground rheostat is built up of cast iron grids, assembled in sections which are separated from each other by porcelain insulators. The whole rheostat is supported upon large porcelain petticoat line insulators. It is necessary to have the parts of this rheostat thoroughly insulated from each other, as the momentary current and fall of potential through it may be very large, depending upon the phase of the e.m.f. wave at the instant of breakdown and the resistance to ground, together with the inductance of the complete circuit including the armatures of the grounded generators and the rheostats, and the capacity of one-phase of the entire system, including all the feeder cables in circuit, which capacity and inductance are in series. So considerable potential surges may be set up, and all or part of the charging current of the system may be added to the ground current and pass through the rheostats.

As the two power stations are normally operated in parallel by means of two, four or six, 3-conductor No. 0 000 feeder cables (the number depending upon the generator capacity in operation) which connect the station high tension bus-bars, and both stations are equipped and operated alike in respect to the grounded neutral, the grounded generators, connections and rheostats in the two stations are also in parallel.

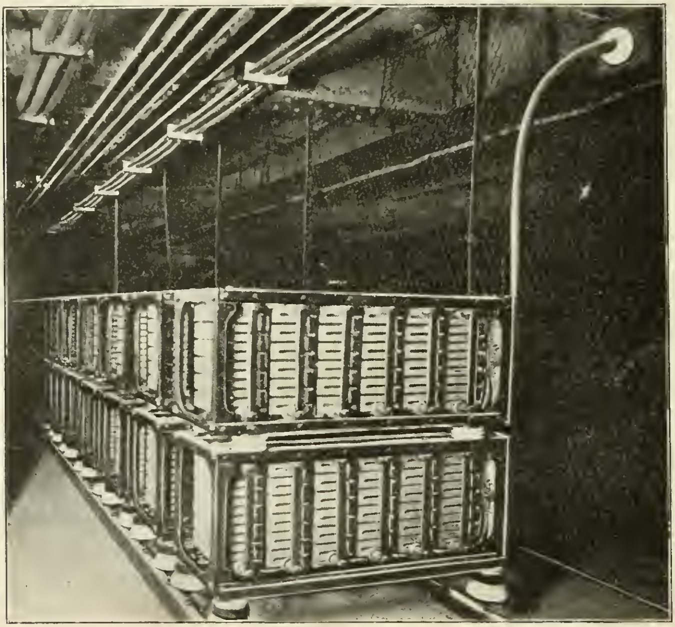

FIG. 3—NEUTRAL GROUND RHEOSTAT AT THE 59TH ST. STATION OF THE INTERBOROUGH RAPID TRANSIT COMPANY

The three 1 250 kw., 11 000 volt, 60 cycle generators, which supply the Subway lighting service are grounded in the same manner, except that no rheostat has yet been installed in the ground lead and there are no current transformers in the leads between the generators and the neutral bus-bar. At present, only one of these generators is run at a time.

The main oil switch of each of the 25 cycle generators is controlled by a triple-pole, bellows type, plain overload relay, all three coils of which are connected to current transformers in the main generator leads. An ammeter on the main instrument board is connected in series with each coil. Originally one relay coil was connected to the neutral current transformer of its generator, and it was intended that the current in the neutral lead should clear a generator from the station bus-bars, in case of a ground in the armature or main leads, and so relieve the rest of the generators of the ground and possible short-circuit. It was found, however, that when a number of generators in parallel were all connected to the neutral bus-bar with only the resistance of the leads and the busbars between them, there was a considerable interchange of current through the neutral. With four or more generators running, if another generator, having its neutral switch closed, was synchronized and connected to the main bus-bar, the momentary flow in the neutral lead exceeded the full-load current of the generator and was not suppressed until the incoming generator had taken its share of the load. After this, an intermittent flow increasing from zero to about one-half the full-load current of a generator and decreasing to zero again, would be indicated by each neutral ammeter in turn in a sort of imperfect cycle in which the generators had a regular order, which, however, was sometimes disturbed without apparent reason. With fewer generators running the neutral currents were less. The current in the neutral had a frequency of 75 cycles and an extremely variable wave form, changing from a simple sinusoid through a whole series of intermediate shapes to a sharp pointed triangular form. There was no apparent interchange of current in the neutral leads betwen the two power stations, and in one station, the insertion of resistance in the leads between the generators and the neutral bus-bar decreased the flow, but rheostats containing the resistance which seemed to be needed to reduce the neutral current to negligibility, would have been too bulky for the space available. For several weeks, both power stations were run with all the generators grounded, and with one pole of each generator main switch relay connected to the current transformer in the neutral lead, but several generators were tripped out by the neutral current just after they had been connected to the station busbars. Because of the difficulties met in preventing the circuit breakers from tripping the plan was modified and now only one generator at a time in each station is run with its neutral grounded.

With very few exceptions, all of the insulation breakdowns which have occurred in the entire system have been in the feeder cables, and for the reasons already given, it is especially desired to protect these against short-circuits. The relays are set to operate instantly at 300 amperes in each sub-station feeder and at 900 amperes in each tie-feeder between the two power stations (consisting of two cables controlled by one switch). The sustained short-circuit current of one generator is about 1 000 amperes and its momentary short-circuit current may be considerably greater. It was judged sufficient to the protection of the cable system to keep one generator in each power station grounded. This affords a current capacity great enough to trip out several feeders, should they ground at the same time on one generator, but if the insulation to ground of two generators should break down at the same time, it is doubtful whether the damaged machines or the one with the neutral point grounded, would trip out first.

This scheme has now been in use for more than a year with very encouraging results. Seven feeder cables have grounded in service, each of which was cut out by the action of its relay without great damage to the cables and so quietly that it was made known only by the oil switch pilot lamps, except in one case. Twice, all of the cables to a single sub-station tripped out together, although only one was grounded, but even then the switches operated easily and without spilling any oil. This is in sharp contrast to the violent and explosive action of the oil switches on short-circuit, which was the rule before grounding the neutral. After the grounded cables had been tripped out, a trial with a high resistance direct-current voltmeter was required to determine the grounded conductor, and the resistance to ground had to be broken down by the transformer used for puncture trials of insulation, before a location could be made. Then the position of the fault was determined by a loop test with a Wheatstone bridge, the whole process of breaking down and locating requiring less than an hour.

A simple and convenient portable slide wire bridge with which to locate cable faults, has been made in the laboratory of the company. The general appearance of one of these bridges is shown in Fig. 4 and a diagram of the connections used in the test is shown in Fig. 5. By means of a table compiled from the records of the cable department, showing the length of each cable and the position of each manhole along it in proportional parts of the total length, the length between the manholes in which the breakdown has occurred can be picked out at once.

Before the neutral was grounded, a short-circuit in a cable was usually preceded by static disturbances in the stations near the ends of the feeder. These disturbances were evidenced by crackling or brush discharges and a strong odor of nitrous oxide which sometimes lasted for hours. When the short-circuit finally occurred, all the cables to the sub-station to which the broken down cable fed, tripped out together, usually at both ends of each cable, and so shut down the sub-station. In a number of cases, the back flow of current from the rotaries to the short-circuit, was sufficient to open all the automatic oil switches in the rotary converter leads and feeders, in all the sub-stations of the division, thus shutting down the entire system fed from one generating station. The switches at both ends of the short-circuited cable always opened very violently, spilling some and often most of the oil in the switch cases and burning the contacts, sometimes even breaking the wooden rods which carry the plungers. The switches of the other feeders to the same sub-station acted in the same way, though in a lesser degree. The power station operator was never in doubt that a short-circuit had occurred and could usually pick out the damaged cable by the appearance of its switch. After grounding the neutral, however, the cables tripped out so easily and with such slight grounds that the operators at one end and sometimes at both ends, might not be aware of the accident until,

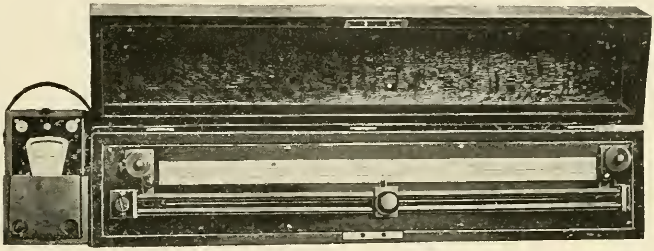

FIG. 4—SLIDE WIRE BRIDGE USED IN LOCATING FAULTS

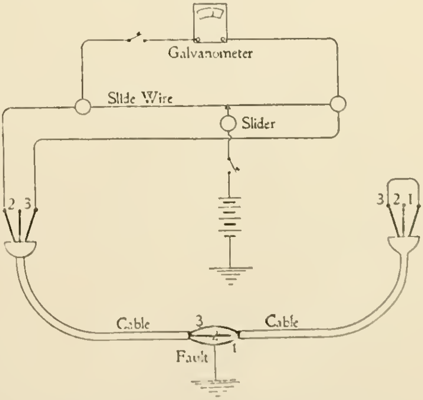

FIG. 5—DIAGRAM OF CONNECTIONS FOR LOCATING FAULTS WITH THE SLIDE WIRE BRIDGE

after several minutes, it was noticed that the pilot lamps of one or more feeder switches indicated that they were open. Then a voltmeter trial was necessary to determine whether a cable was grounded. Accordingly a relay was connected to the current transformer in the lead from the neutral rheostat to ground, which, when tripped, closes a local circuit which lights a red lamp on the instrument board that glows till the relay is restored by hand. The ground signal lamps in both power stations light when there is a ground anywhere in the 25 cycle primary system, so that they also give notice of accidental grounds due to mishaps or carelessness that would otherwise never be known. A similar ground signal is attached to the 60 cycle lighting system of the Subway division.

Slight static discharges that caused an almost continuous odor of nitrous oxide were common in certain parts of the system. They apparently were not followed by any serious results and have quite disappeared.

In conclusion, the results of grounding the neutral in this plant have been, so far, entirely advantageous.

THE PURPOSE OF THE ELECTRIC CLUB

F. D. NEWBURY
President of the Electric Club

THE story of the inception of the Electric Club has been told a number of times to Electric Club audiences, but it will be new to the great majority of JOURNAL readers, and it has an interesting and important bearing on the subsequent development of the underlying purpose that has given direction to the work of the Club. The story is worth repeating.

During the winter of 1901 a successful and highly profitable series of technical lectures was given by the engineers of the Electric Company in an unused room in the office building at East Pittsburg. Before the following fall this room was required for the regular work of the Company and no other suitable room in the building was available. On account of this, no lectures were given during the winter of 1902 but the project was by no means forgotten. The benefit from the lectures of the previous season had been so obvious and the young men of the Electric Company were so desirous that they should be continued that it was felt that some means for doing so should be found. It was suggested that a suitable hall in Wilkinsburg (where most of the apprentices live) be rented two or three evenings a week during the winter season. This plan received the approval of the management of the Electric Company and the search for a suitable hall was started. Following the suggestion of this plan other plans were rapidly proposed. Why not have smaller meetings than lectures in which the construction of apparatus, methods of its design, manufacture and operation could be informally talked over and discussed; why not have regularly organized classes for the study of elementary theory—this for the shopmen; why not have a reading room; why not have other things than technical meetings—social gatherings, dances and entertainments, in short, why not have a club? This meant, instead of renting one room two or three nights a week for part of the year, the renting of an entire floor of a large building all of the week for all of the year. But this rather startling growth of the originally modest plan did not frighten the management of the Electric Company from whom financial support was asked. On the contrary, it received their cordial approval, and the Electric Club was formed. This was done at a general club meeting held March 19, 1902. It is unnecessary to add, except for the benefit of those outside of our Westinghouse community, that the man back of these suggestions and plans and back of their successful fruition was Mr. C. F. Scott, the consulting engineer of the Electric Company.

During the four years since its organization the Club has been, on the whole, successful in the work it has undertaken and has gained a valuable and interesting store of experience. It is beyond the scope of the present article to trace the growth of this experience. Each branch of club-work—its technical sections, its lectures, its excursions, its entertainments, its athletics, THE ELECTRIC JOURNAL, has a history of its own, any one of which would make an interesting story. The club has become a community in which different groups of men are interested in various things yet in which all are held together by the bond of a common employment. The present article will point out one result of this growth in experience—the development of the conception of the purpose of the club. The nature of this conception is fundamentally important; it has determined and will continue to determine the direction and extent of the growth of the club.

When the club was organized its purpose was primarily educational. The formation of the club was the direct result of the extension of a series of technical lectures. Naturally, then, when the club was formed, its lectures and other technical interests were considered first; its entertainment work, although of considerable extent, came second. This point of view made an engineering society of the club and attracted to it a membership interested primarily in technical things.

During its third season, during 1904-5, a new conception of the club's purpose became apparent. The members desired a club in which the relative values of social and technical work would be interchanged. The club should become, relatively, more of a club and less of a school. This did not mean that the members desired any reduction in the actual extent of the technical work undertaken by the club. They did desire an increase in the facilities for social life in the club and an increased appreciation of the value of social intercourse among club members. The new idea received the active support of those in charge of the club. Coming, as it did, from the members, it indicated on their part an active interest in the development of the club that the officers were very glad to encourage.

This new idea was stated, in an announcement to club members made at the beginning of the fourth season, in these words:

"The club must be fundamentally a sociable club. Sociability and entertainment, however, are not ends in themselves; they are the means for the accomplishment of the serious work of the club. The club is something more valuable than a social club, but the social life is the center; from it will grow the membership and spirit that will make effective work in other directions possible."

This is the platform on which the club was run during the past season. During the year this idea of a "sociable club" developed; gradually crystalizing out of the year's experience, it grew into a new and broader conception of the club's purpose. Today, this purpose can be stated broadly, yet very simply; *to aid in the symmetrical development of Westinghouse men.* It is even more than this; it is to develop men, to fit men, in body, mind and soul, to do, well and cheerfully, the work they are here to do.

This conception of its purpose gives the club a new point of view. The field of the club's legitimate activity is widened immensely. No work or form of endeavor that will aid in the development of better and broader men is outside of its purpose. The extent and variety of its work need be limited only by the spirit of its members and its material equipment. The work the club has already accomplished, as great and as valuable as it has been, bears only a small ratio to the work the club can do, provided its members are equal to the task and the necessary material facilities are provided. Of these two requisites, the former is the most important and must show itself first. The growth of the club work to the extreme limit is up to the club members. The club will be what they make it.

This broad conception of the purpose of the club not only extends the range of the club's activity but gives a new significance to whatever work it undertakes. In the early days of the club, an entertainment was simply an entertainment; its success was measured by the enjoyment of those who attended it. At the present time an entertainment is not only an entertainment but it is an opportunity for a number of men to develop their initiative and sense of responsibility, their knowledge of human nature and of the inertia of things. The success of an entertainment, judged by this point of view, does not depend so much upon its value to the men who passively attend it as upon its value to the men who actively work for it. The man who gets the most out of college is not the "grind" who devotes all of his time to the acquisition of knowledge. It is rather the man who devotes a reasonable time to study and takes time to play his part in student organizations, and in so doing learns to use his knowledge among men. Likewise in the apprenticeship course, it is necessary not only to learn facts, but to learn how to use them in doing things. The valuable man is not necessarily the man who is technically the wisest; he is sometimes the man who knows less technically, but, by a knowledge of human nature, a human sympathy and a smiling countenance, compels men to work with him and for him. The opportunity the club gives the younger men to "manage things" is one of the most valuable of club privileges.

When the broad purpose of the club is understood, it should bring a vastly larger number of men into sympathy with its aims and work. An engineering society will interest one group, a tennis club another group, a social club still another group, but a club whose purpose is the development of Westinghouse men will interest every man who has an interest in the development of the Westinghouse companies. The Electric Company, for example, brings to its works every year between two and three hundred young men as apprentices who will, to a considerable degree, constitute the future personnel of the company. It is of fundamental importance that these young men should receive a good training. Their technical training in the shop and office is only a part of it. They must become Westinghouse men in spirit as well as in fact. They can catch this spirit only by associaton with men who already possess it. In a small community this association can be accomplished without organized effort, but in a large community, containing hundreds of men, a highly organized means for bringing these men together under pleasant social conditions becomes necessary. This constitutes one of the most important opportunities of the Electric Club. To make the most of the opportunity the club should have greatly increased facilities, but with its present material equipment it has accomplished much in this direction, and can accomplish still more.

SOME INTERESTING ELECTRICAL LABORATORY APPARATUS

C. R. DOOLEY

THE new electrical laboratory of the Casino Technical Night School, which has recently been completed, contains, in addition to the usual equipment for such laboratories, a number of pieces of special apparatus. This apparatus has been fitted up by the students of the school who have taken an active part in the construction of the laboratory equipment. The arrangements used for studying induction motor winding and a form of small prony brake, as described below, are two interesting examples.

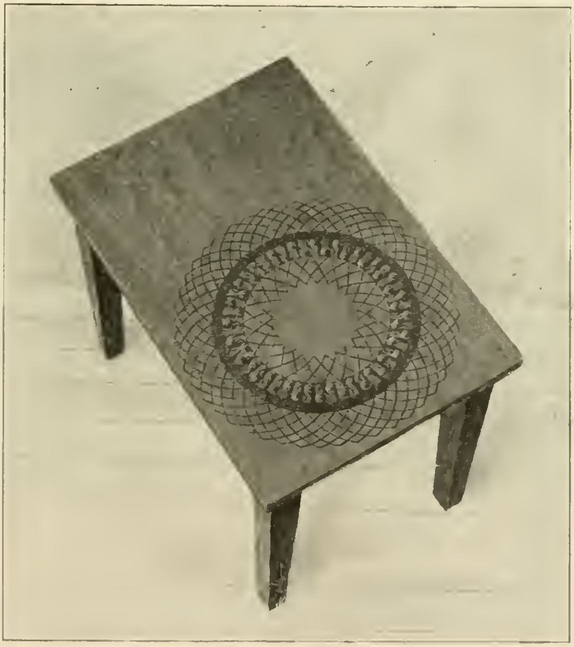

FIG. I

A LABORATORY METHOD OF STUDYING INDUCTION MOTOR WINDINGS

For the study of induction motor windings a diagrammatic method is employed. The induction motor used is an ordinary cage wound machine with 48 coils wound in 48 slots. Inside the motor the coils are connected in pairs, thus forming 24 groups of two coils in series. From each group two terminals are brought out so that there are 48 terminals in all. These groups of coils are connected by flexible leads to a table placed near the motor. On the top of this table the outline of a complete punching from the stator of the motor is painted in dark red. The coils in the motor are represented in their true positions by black lines as shown in Fig. 1. At the ends of each group in the diagram binding posts are placed which extend through the top of the table. The leads from the various coils in the motor are brought up under the table as shown in Fig. 2 and connected to the binding posts on the corresponding positions of the diagram. The coils lie in slots one and nine which corresponds to the pole pitch for a six pole connection and forms a good chord for a four pole connection. With the coil terminals brought out in this way the winding arrangement is plainly shown and the coils can be connected for any desired combination by connecting the proper binding posts together with short wires. With this motor, connections may be made for four poles, either two or three phase; and six poles, two phase. Each combination connected up will require a slightly different impressed voltage if the same performance is to be given by the motor. The ratio

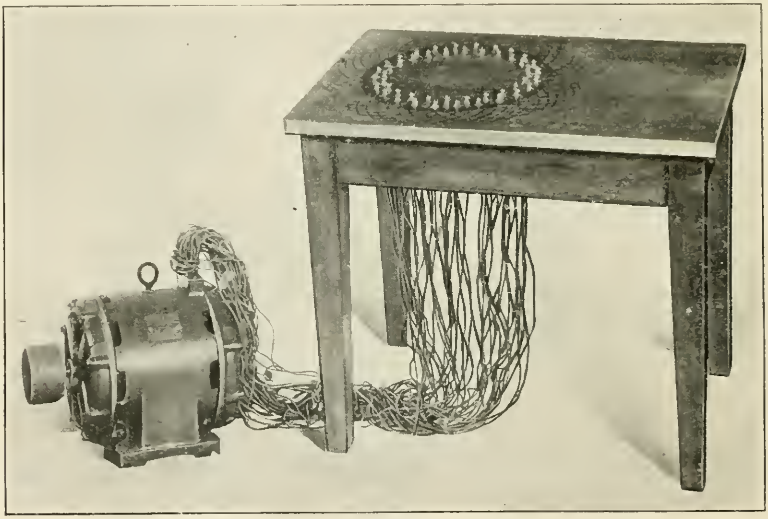

FIG. 2

of two to three phase voltage for the same total number of conductors may be determined.

Aside from these small variations of the impressed voltage, the groups of each phase may be connected in several different parallel combinations, giving, in some cases, three distinct voltages, as for instance: 100, 200, or 400 volts. Readings of impressed voltage, current, speed and the voltages between different binding posts can be taken to determine the correctness of any diagrammatic connections.

PRONY BRAKE FOR SMALL MOTORS

The ordinary prony brake as arranged for water cooling requires two water pipes, one for the entering cool water and another fitted with a scoop to drain the hot water from the inside of the brake pulley. With small brakes it is difficult to adjust the scoop. The diameter of the brake pulley is necessarily small and often it is difficult to adjust both pipes in such a small space. The water must be shallow in these small pulley rims and the scoop must be placed very near the rim of the pulley in order to drain the water properly. Under these conditions any slight jar or even the constant vibration from the motor may move the scoop from its adjustment. Aside from the inconvenience and the liability of the scoop rubbing against the pulley, there is the constant friction of the scoop on the rotating cylin-

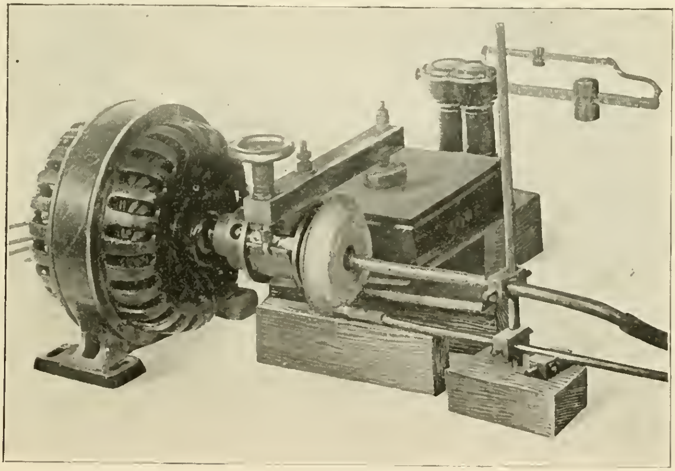

FIG. 3

der of water which may be a considerable item in the case of small motors.

To overcome these difficulties the apparatus shown ready for use in Fig. 3 and in detail in Fig. 4 was built. A brake pulley is used which is provided with a flange of the form shown in Fig. 4. Water is lead into the pulley by a small pipe in the usual manner and when sufficient water has entered to fill the rim to overflowing it is thrown out by centrifugal force and flies off the edge of the flange. A metal V-shaped case fits closely around this flange as shown in Fig. 3 and catches the water as it is thrown from the flange. A drain pipe in the bottom of the case carries the hot water away. This apparatus operates very satisfactorily and without any throwing of water when stopping and starting as is often the case with the usual arrangement.

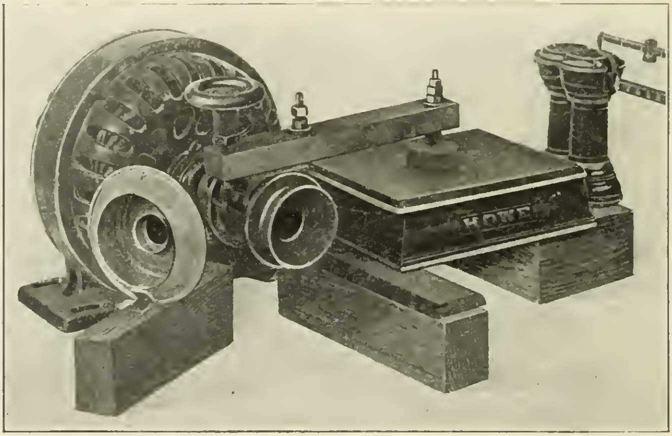

FIG. 4

TESTING LARGE MOTORS, GENERATORS AND MOTOR-GENERATOR SETS—II

C. J. FAY

LOADING BACK LARGE DIRECT-CURRENT RAILWAY MOTORS

THE method of loading back direct-current series motors is somewhat different from that for compound or shunt wound machines. Several methods have been tried and found to work under special conditions, but not adapted to commercial testing. In loading back tests on series railway motors the two machines to be tested are mounted on a stand with their shafts in line and coupled together. In testing these machines it becomes necessary to separately excite the field of the machine running as a generator. Not only this, but as the machine running as a generator has to furnish the current taken by the machine running as a motor, it follows that, if the motor is taking full-load current, the generator will be overloaded, as the losses are not supplied from an outside source in parallel as is the case with shunt and compound machines. For this reason it is customary to use a booster to raise the voltage of the generator so that it will not be necessary to over-excite the generator field. By controlling in this way, that is, by connecting the two machines together so that the motor is in parallel with the generator armature (with booster in series) so that a change in one will give a corresponding change in the other, an arrangement is obtained which will work at any load within the limits of the design of the machines with very little consumption of power and without very much care and attention.

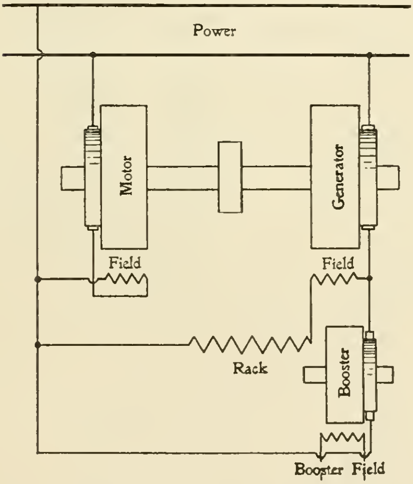

FIG. 1—OUTLINE DIAGRAM OF CONNECTIONS

Fig. 1 shows the general scheme of connection. Fig. 2 shows the connections on the switchboard used for this test. By the use of this switchboard either machine can be run either as a motor or generator as desired, and in either a clockwise or counter-clockwise direction of rotation. The machine terminals are connected to the switchboard terminals marked *A* and *F* in Fig. 2. If machine No. 1 is to run as a motor, switches 1, 2, 3, 4 and 7 are thrown to the left, 5 and 6 may be thrown either way, depending on the way the motors are connected to the terminals and also upon the direction in which they are to run. Switch 10 is thrown to the right, while 11 is thrown to the left, if the power is to come from the shop 500 volt circuit or to the right if it is to come from the testing plant for very close regulation or for voltages other than 500.

The booster field may be excited from the

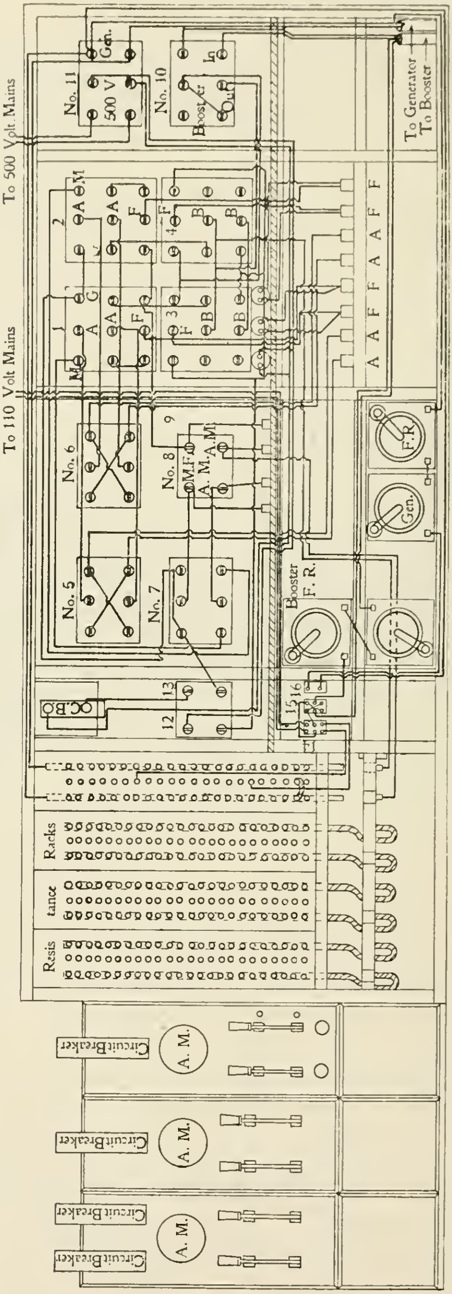

FIG. 2—DIAGRAM OF CONNECTIONS OF SWITCHBOARD FOR TESTING LARGE RAILWAY MOTORS

110 volt shop mains by throwing switch 14 up or from the testing plant by throwing the switch down. Switches 8 and 9 are always closed except when reading current in the armature or field. Switches 14 and 15 must be closed to get a field on the booster. The starting controller is placed across the terminals of switch 12. With the starting controller on the first notch and the circuit breaker and switch 13 closed, the motor will start if all the connections have been properly made. With one connection made wrong the motors will not start. If the machines start on the first notch the controller can be brought gradually around to the last notch and then short-circuited with switch 12, when the machines will be running under full voltage ready for load. The current in the generator field is controlled by the use of resistance racks in series with the field. If the resistance is set so that the field is not over-excited at the rated load of the machine, it seldom becomes necessary to change it except for very heavy overloads. All ordinary changes of load are made by either increasing or decreasing the field of the booster as the case may require.

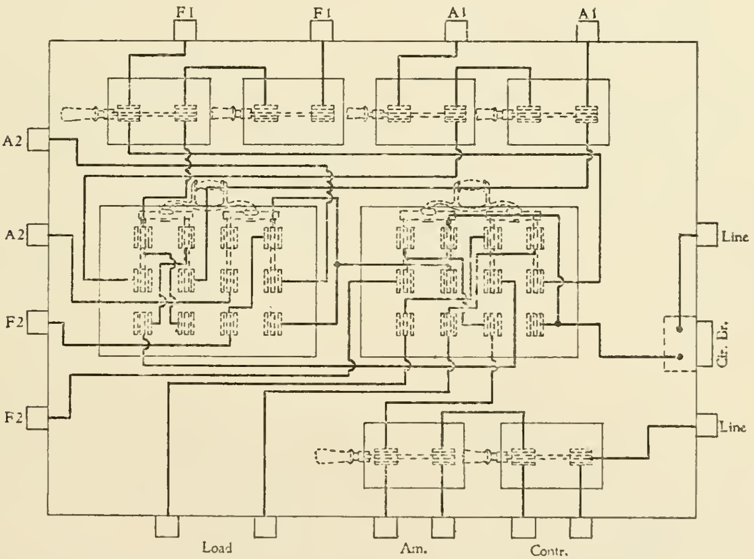

FIG. 3—DIAGRAM OF CONNECTIONS OF SERIES MOTOR TABLE

Before any running tests are made the cold resistance of the armature and field are taken, along with the corresponding temperatures of the windings. These readings are reduced to a standard temperature of 25 degrees C. by use of the formula, —$r_{25} = r_t \left(\frac{1.105}{1 + 0.0042t}\right)$ in which r_{25} is the resistance at 25 degrees C, t is the temperature in degrees C. at which the readings were taken—and r_t is the resistance at the temperature t.

For example, the resistances taken on a 200 hp, 570 volt railway motor were, armature, 0.03495 ohm; field, 0.0369 ohm, at 23 degrees C.

At 25 degrees C. these resistances become:

$$0.03495 \times 1.0076 = 0.0352 \text{ ohm.}$$
$$0.0369 \times 1.0076 = 0.0372 \text{ ohm.}$$

After the machines have been connected to the line the field of the booster and the resistance in series with the generator field are regulated to give the maximum load desired for a speed curve. Readings of line volts, line amperes, field volts and speed are taken at this load and at various loads down to the load which gives the maximum speed at which the machine is designed to run. For example, the following readings were obtained for one point on the speed curve of the motor mentioned above:

Amp.	Volts	Field Volts	Speed
400	570	15.9	556

Two sets of readings are taken, one for clock-wise and the other for counter-clock-wise rotation. When these readings have been obtained they are corrected to a temperature of 75 degrees C. and plotted in the form of curves.

For example, at 400 amperes, counter-clock-wise rotation, 15.9 field volts, the speed was 556 r.p.m. by test. At 75 degrees C. the resistance becomes twenty per cent greater than at 25 degrees C. or armature = 0.0422 ohm and field = 0.0446 ohm. As the speed of a motor is proportional to the counter e.m.f., the c.e.m.f.'s are determined for the different temperatures and the speed for 75 degrees C. can then be calculated.

The e.m.f. applied to the motor is known, also the field resistance. The ratio of motor to field resistance =

$$\frac{\text{Field Resistance + Armature Resistance}}{\text{Field Resistance}} = \frac{0.0422 + 0.0446}{0.0446} = 1.955.$$

Then proportionally the total CR drop in the motor = $15.9 \times 1.955 = 31.05$ volts.

The c.e.m.f. then at 25 degrees C. $= 570 - 31 = 539$ volts.

At 75 degrees C. the CR drop in the motor $= 400 \times 0.0868 = 34.7$ volts.

The corresponding c.e.m.f. $= 570 - 34.7 = 525.3$ volts.

Then the speed at 75 degrees C. $\doteq 556 \times \frac{535.3}{539} = 560$ r.p.m.

TESTING LARGE SINGLE-PHASE RAILWAY MOTORS

At present single-phase railway motors are not tested on alternating current by the loading back method but are run either belted to generators loaded on resistance or with prony brakes. The usual tests made on these motors are resistance readings, saturation, speed and torque curves, and heat runs.

The saturation curves are taken by belting the single-phase motor to a direct-current shunt motor and driving it at constant speed. Readings are then taken, with varying field current, of armature and field amperes, field watts and speed.

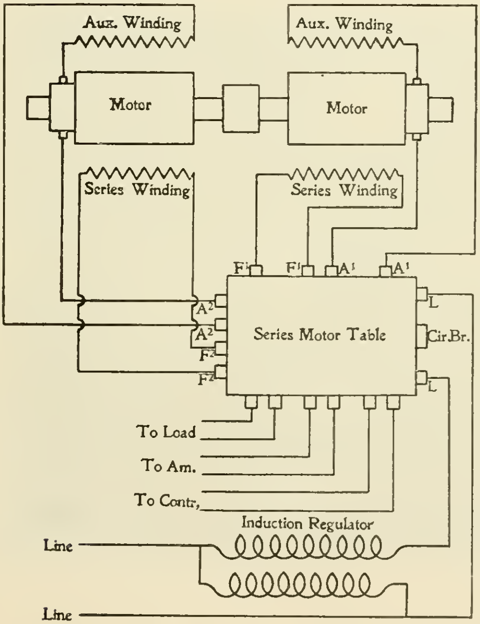

FIG. 4—DIAGRAM OF CONNECTIONS TO SERIES MOTOR TABLE

For a torque curve the motor is fitted with a prony brake and connected to a series motor table, the connections of which are shown in Fig. 3. Readings of line amperes, volts, torque and speed are taken for various loads from the maximum load down to the load giving the maximum speed at which the machine is designed to run.

For the speed curve the motors are coupled together and connected to the series motor table as shown in Fig. 4. One is run as a generator to load the other as a motor, the generator being loaded on a resistance. Either machine may be run as a motor as may be seen by following out the connections of the table shown in Fig. 3. Readings are taken of field and armature volts, line amperes, line and field watts, and speed. The line voltage is held constant by a motor-operated induction regulator controlled by a two-way switch at the testing table. While the readings for the speed curve could be taken while taking the torque curve, they would not be as satisfactory because the load is not so steady as it is with the loaded generator. Fig. 5 shows a pair of large single-phase motors under test, illustrating the method used for testing enclosed motors arranged for forced ventilation. A view of the testing board used for the large direct-current motors may also be seen.

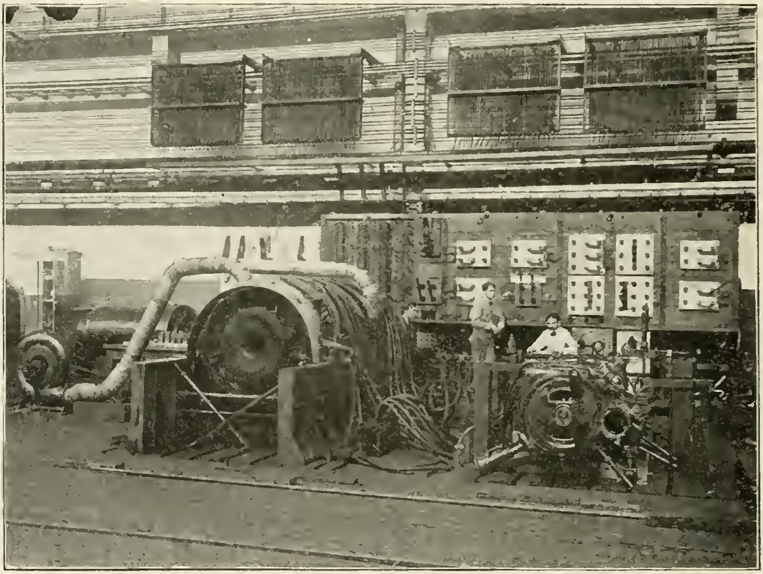

FIG. 5.—VIEW OF TWO LARGE RAILWAY MOTORS UNDER TEST WITH FORCED VENTILATION

THE VALUE OF OSCILLOGRAMS IN CONNECTION WITH AUXILIARY-POLE MACHINES

J. N. DODD

IN a recent article on "Mechanical Aids to Commutation,"* reference was made to the use of auxiliary poles and to the method by which their proper strength can be determined by means of records from an oscillograph connected to two adjacent commutator bars.

A very close approximation to the shape of the magnetic field of a machine may be obtained by plotting a curve showing the volts per commutator bar. For any ordinary direct-current machine this curve at no load would have a shape of which the full line curve in Fig. 1 is a type. The full-load curve of this machine would be the combination of this curve with a curve due to the armature magnetization. This curve of armature magnetization is at approximately ninety degrees from the no-load curve and would be of a form shown by the dotted line in Fig 1. The order to have perfect commutation the volts per bar under the brush should be zero. Therefore the brushes must be shifted forward to a point where the volts per bar are zero, that is to the points A A_1 in Fig. 2. If this machine is provided with auxiliary poles they must be of such strength as to annul the effect of the armature reaction at the brushes, or in other words, to give zero volts per bar at this point. The auxiliary-pole curve should be of the form shown by the dot and dash line in Fig. 1. The combination of this curve with the full-load curve will give the curve shown in Fig. 3 and should give perfect commutation. This can be illustrated by an example taken from actual experience. Fig. 4 is the no-load field form, as taken by an oscillograph, of

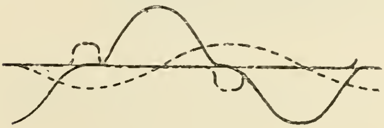

FIG. 1

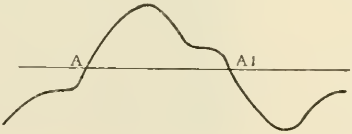

FIG. 2

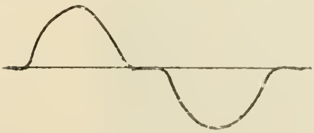

FIG. 3

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*See *The Electric Journal*, Vol. III., No. 6.

a machine provided with auxiliary poles. This curve is perfectly symmetrical so that the direction the machine is running cannot be determined from the curve. The neutral or zero voltage spaces, while narrow, are of sufficient width to allow perfect commutation. Fig. 5 shows the oscillograph curve of the same machine under load. Two points may be noted. First, the field is distorted. Consequently the direction of rotation may be told as the field is pulled over in the direction the ma-

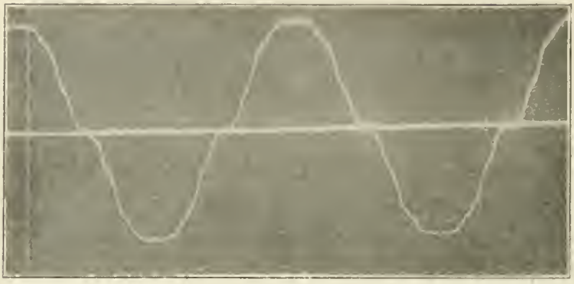

FIG. 4

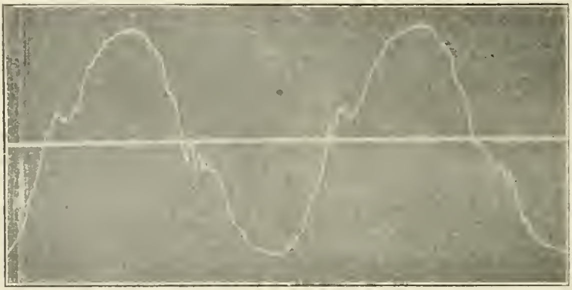

FIG. 5

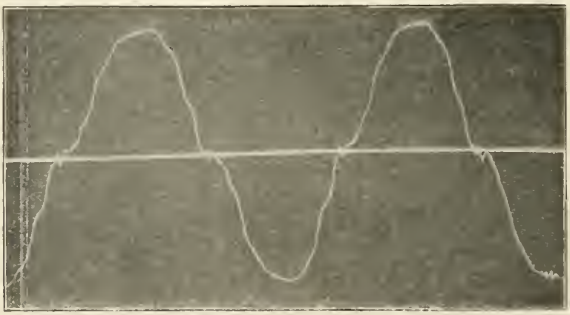

FIG. 6

chine is running. Second, it may be seen that the auxiliary field is too strong. Without the auxiliary field the field from the main pole is pulled over into the brushes. On this machine, however, the reversing effect of the auxiliary fields is so strong that the voltage at the brushes is reversed from what it would be without the auxiliary fields. The commutation in this case was bad. The oscillograph curve shown in Fig. 6 was taken with the same load but with the auxiliary fields shunted until perfect commutation was obtained. It may be seen that in this case the voltage at the brushes is zero, as might be expected.

An interesting case is where the main fields are very weak and the armature is very strong. The results should be as shown in Figs. 7 and 8. That is, to obtain perfect commutation the strength of the auxiliary field should be equal to the strength of the armature field at the brushes. The fact that the field is distorted past the brushes, that is, that we have the same polarity on each side of the brush, does not interfere with perfect commutation.

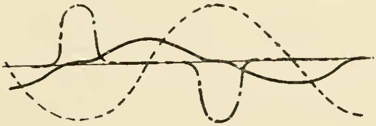
FIG. 7

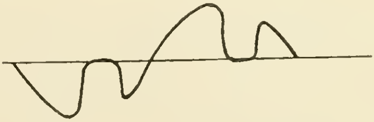
FIG. 8

An illustration of this may be seen from Figs. 9 and 10 which are oscillograms of a machine running under the conditions given above, namely, with a weak main field and a strong armature. Fig. 9 is with poor commutation. With Fig. 10, although the commutation was not perfect nevertheless the voltage during commutation was kept down to a low figure and the commutation was good.

The difference between auxiliary poles and the Ryan or Deri winding may here be pointed out. In the Ryan or Deri winding the field, instead of consisting of salient poles, consists of a continuous ring entirely surrounding the armature. The auxiliary winding is distributed over the face of this ring, the object being to annul the armature magnetization over its whole extent. That is, the shape of the field caused by the auxiliary wind. is identical with the armature field but in the opposite direction instead of being of the same value only at the brushes as with auxiliary poles. It possesses certain advantages over the use of auxiliary poles. These advantages may be seen by an inspection of Figs.

7 and 8. With a machine of the characteristics shown in these two figures with auxiliary poles the full load volts per bar and the armature induction are as shown in Fig. 8. With the Ryan or Deri winding (compensated winding) they are as shown in the full line of Fig. 7. On account of the value of the volts per bar a dirty commutator can cause much more trouble with auxiliary poles than with compensated winding.

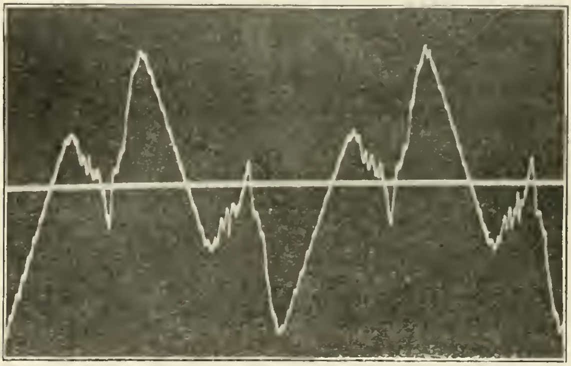

FIG. 9

With regard to the induction it will be noted that with a compensated winding for every cycle of the armature the value of the induction at the surface of the armature has two distinct maxima and these are low while with auxiliary poles there are four distinct maxima and for each of these the induction is high. That is, the iron loss is increased because the frequency is doubled and induction is much higher.

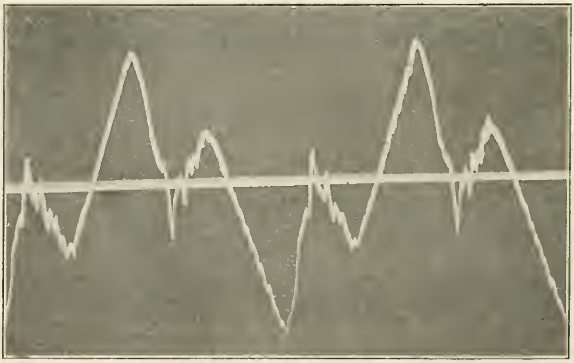

FIG. 10

FREQUENCY METERS

F. CONRAD

IN THE commercial measurements of electrical quantities, that of current is the only one in which the measurement is directly referred to the quantity in question. In an ammeter the effect produced by the current is directly the means of indication. For measurement of potential it is necessary to refer to the current which will flow in a circuit of known resistance. A possible exception to this may be found in the "spark gap" method of potential measurements. In the measurement of frequency we are dealing with the cyclic changes of another quantity, that of potential, and, as usually the changes occur too rapidly to be observed directly by a potential measuring device, it is also necessary to resort here to an indirect method of observation.

Instruments now in commercial use operate on one or the other of the following principles, namely, the sensitiveness of a vibrating reed to respond to an operating force of the same frequency only, and the change in impedance produced in inductive circuits by change of frequency.

Instruments of the first type usually consist of a number of steel reeds tuned to various pitches over a certain range of vibration. The reeds are placed within the attractive influence of a magnet which is energized by a potential, the frequency of which it is desired to obtain. The general construction of an instrument of this type is comparatively simple as it has no moving parts on pivots or bearings. To obtain the best results it is necessary that the potential be maintained at a value which does not differ greatly from that for which the instrument has been designed, as with too low a value the amplitude of vibrations will not be sufficient to be readily observed. With too high a value a number of reeds differing in pitch from that of the circuit may start into vibration with varying amplitude as they come into and out of synchronism with the magnetic field. In view of this, and from the fact that at the best the readings are largely a matter of estimation this type of meter has not come into very extended use in this country.

A simple instrument of the second type would consist of an ammeter connected in circuit with an impedance of known value and across a circuit of known potential. From the current reading obtained and the known value of potential and impedance, the frequency may be obtained by calculation. To make the instrument direct reading it would be necessary to maintain the potential at some fixed value or to introduce some compensating device in the instrument, the latter principle being the one employed in most instruments now in commercial use.

The construction in general consists of an operating element in series with an inductive resistance and a retarding or compensating element in series with a non-inductive resistance. No controlling spring is used, the retarding element taking its place. If the torque of the operating and retarding element varies in the same ratio with changes of voltage, the instrument will give indications which are independent of changes of voltage.

The chief causes which would produce variation of reading with change of voltage are:

1—Increase of non-inductive resistance due to heating on high voltages.

2—Change of permeability of iron in inductive resistance with change of current.

3—Dissimilarity of ratio between torque and voltage of operating and retarding elements.

The first may be minimized by keeping the heating effect of the current low and using a wire of low temperature coefficient. The second will always be present to a greater or less extent, but it may be corrected by combining it with the third in such a proportion that the two will cancel out.

The general construction of the instrument may be such that it will harmonize in appearance and method of reading with that of other instruments which may be used in the same installation, and from the manufacturers' standpoint it possesses the advantage of using parts which are interchangeable with other instruments such as voltmeters and ammeters.

EXPERIENCE ON THE ROAD

O. H. CROSSEN

In a certain plant in the Middle West the rotary converters formerly gave trouble during electrical storms by going out of phase with the generators. The sub-station in which the converters are located is in the central part of the city and receives its power from the main power station, nineteen miles away. The transmission voltage is 10 000 volts, three-phase, 60 cycles. The voltage is lowered to 350 volts at the sub-station for the rotary converter and motor-generator sets. There are two compound-wound converters of 175 kw capacity, each built to give 550 volts direct-current. The trouble with the converters had been obviated by using a motor-generator set for separately exciting the fields of the converters. A diagram of the connections used for this purpose is shown in Fig. 1. To separately excite the converter, if it is running self-exciting, the potential of the generator of the exciting set is adjusted to that of the converter and the plug switch, Fig. 1, is closed and the field changing switch moved from position *1* to position *2* or vice versa. The exciter runs in parallel with the converter while switching over as the blade of the field changing switch is in contact with the negative side of the converter circuit and also the negative side of the exciter circuit at the same time. The plug switch connects the

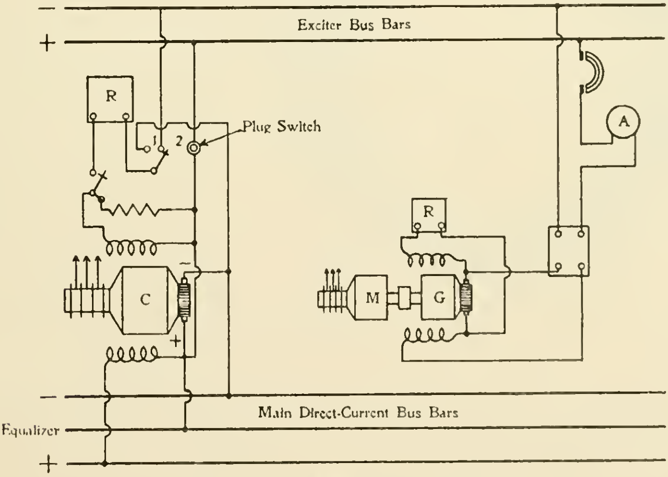

FIG. 1—DIAGRAM OF CONNECTIONS

positive sides together. These changes and the use of the connections as shown proved quite satisfactory.

These converters were built before it became the practice to put dampers on the pole tips. Dampers were, however, put on some time after the machines were installed. They were of the earlier type consisting of a ring of copper around the pole tips. When the machines were in use these dampers became quite hot and heated the shunt field coils thus increasing their resistance until it was impossible to get a high power-factor after the machine had been running for a few hours. This made the line loss large and the regulation of the direct-current voltage poor. A rather unusual method was taken to increase the shunt field. Auxiliary shunt field coils were wound on forms and put on over the shunt fields as shown in Fig. 2. The following may be found useful as showing the method used in finding the size of wire and ampere-turns of the auxiliary winding necessary to give a high power-factor after the machine had heated up.

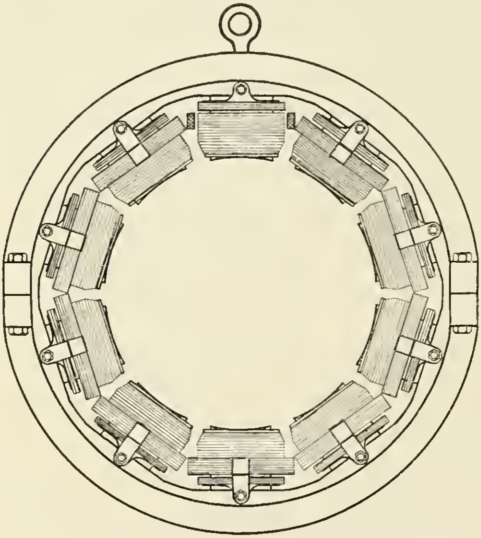

FIG 2—VIEW SHOWING EXTRA FIELD TURNS IN POSITION

SHUNT FIELD RESISTANCE

Readings taken before and after a run of fifteen hours.

Cold Air—26° C.		Hot Air—26° C.	
Volts	Amperes	Volts	Amperes
520	5.97	520	4.86
570	6.65	570	5.32
600	6.89	600	5.60

At full-load and normal frequency with a shunt field current of 6.55 amperes and the direct-current voltage at 570, one hundred per cent. power-factor could be obtained.

The resistance of the shunt field at 26 degrees C. was 87 ohms. After a run of fifteen hours the temperature was 85 degrees and the resistance was 107 ohms, and the shunt field current had fallen to 5.32 amperes. The number of turns can be found by dividing the resistance of the winding by the resistance of one turn. The average length of a turn can be ascertained by measuring a field coil, making a drawing of the same and finding the average length graphically. The average length was found to be 55 inches.

The resistance of a thousand feet of No. 13 copper wire at 26 degrees is 2.045 ohms, the resistance of one turn is 0.00937 ohms.

$$\frac{87}{0.00937} = 9281 \text{ turns. There are ten coils, hence}$$

$$\frac{9281}{10} = 928 \text{ turns per coil.}$$

If the machine will give the required power-factor when cold, it is evident that the additional number of ampere-turns required for the field is equal to the difference between the ampere-turns that the machine will give when cold and when hot.

The ampere-turns when the temperature of the field coils was 26 degrees at 570 volts $= 9\,280 \times 6.55 = 60\,784$ ampere-turns. The maximum ampere-turns when the temperature of the coils was 85 degrees with 570 volts $= 9\,280 \times 5.32 = 49\,370$ ampere-turns. The required additional ampere-turns $= 60\,784 - 49\,370 = 11\,414$ ampere-turns.

In finding the size of wire required the available winding space should be measured. It was found that a coil one inch thick by two and one-quarter inches wide could be used. Allowing for insulation a coil seven-eighths of an inch thick could be used. The mean length of one turn was found to be 5.5 feet. The required size of wire is given by the following formula, allowing ten per cent. for regulation with a rheostat:

$$\text{Area} = \frac{12 \times L \times AT}{E} \qquad \frac{12 \times 5.5 \times 11\,414}{570 - 57} = 1468 \text{ circular mils.}$$

The nearest gauge size to that era is No. 18, with 1 645 cir. mils.

The current density in coils placed over hot coils must necessarily be low, say about one thousand circular mils per ampere. Allowing a rise in temperature of 30 degrees the resistance of the winding at 56 degrees should be $\frac{570}{1.64 + 0.16} = 317$ ohms and the current at 570 volts, 1.8 amperes. The resistance of a thousand feet of No. 18 copper wire at 56 degrees is 7.263 ohms or 0.007263 ohms per ft. The length of the wire in the winding will be $\frac{317}{0.007263}$ = 43 645 feet. The length of the wire in the winding divided by one turn will give the number of turns, $\frac{43\,645}{5.5} = 7\,935$ or $\frac{7\,935}{10}$ = 793 turns per spool.

The available winding space was seven-eighths of an inch by two and one-eighth inches. The number of turns per square inch of No. 18 single cotton insulated copper wire is 448. Turns per spool, 793. $\frac{793}{448} = 1.77$ sq. in. Width of coil $= \frac{1.77}{0.875} = 2.02$ inches.

The available ampere-turns, allowing ten per cent. for regulation $(1.8 - .18 = 1.62) = 1.62 \times 7\,930 = 12\,846$. The required ampere-turns was 11 414.

After this winding was completed a rheostat was put in series with the circuit to vary the current from 1.8 to 1.62 amperes. It was set to give 1.75 amperes with 570 volts and left in that position. The field current was regulated with the rheostat in the main shunt field circuit. After the auxiliary shunt field coils were put on the current in the main shunt field was lowered with a rheostat. This lowered the temperature so that the converters could be synchronized hot without first separately exciting the field as had been done before. Also a leading power-factor could be obtained if the voltage was not more than five per cent. high and the frequency not more than four per cent. low. It was desirable that the converters give a leading power-factor to bring the power-factor of the total load up, as part of the load was induction motors and series arc transformers.

A METHOD OF COMMUTATOR GRINDING

It was found that the commutation was improved by using the brushes themselves for grinding the commutators. For this purpose the machine is driven by the small starting motor on its shaft, and its field circuit left open so that no electro-motive force will be generated. Light engine oil is then applied to the commutator with a cloth. Within from three to five minutes the surface of the commutator will be ground smooth due to the cutting of the brushes.

THE
ELECTRIC JOURNAL

VOL. III. OCTOBER, 1906 NO. 10.

Methods of Train Operation

The question of locomotives vs. multiple-unit car equipments taken up by Mr. Street in this issue of the JOURNAL is of just as great interest now as when the locomotive system received its first defeat at the hands of the multiple-unit system some years ago. Each system undoubtedly has its own field of operations; for instance, no one would think of operating the trains in the New York Subway with locomotives, and it is a bold man who would start equipping all the cars on steam rairoads which are considering the adoption of electricity, with motor and control equipments. But there is a field intermediate between these two where the line is not so sharply drawn and where either system would operate with fair satisfaction.

The curves shown in Mr. Street's article point out the disadvantages of the locomotive in handling trains of widely varying weights, but it is conceivable that in many instances where the sizes of suburban trains are not so widely different that locomotives could easily be adopted for such service and operate economically. It is probable that such service would be better handled by small locomotives operated on the multiple-unit system than by very large units, since the greater the subdivision of power the better variations in the size of train may be cared for. For such service small locomotives with one end fitted up with a baggage compartment would operate very satisfactorily. For through service the locomotive will continue to be used until the system of electric traction is so standardized that any equipment will operate on any line. Present indications are that this date will appear a few months this side of the millenium, but there is some possibility of shortening this time. In the meantime each proposition should be considered by itself and the decision between locomotives and multiple-unit equipments made on their own merits.

N. W. STORER

Unforseen Consequences in Engineering

I recall a statement by a writer upon political affairs to the effect that the unforeseen consequences of a new law were apt to exceed those which were anticipated.

The same principle applies in engineering matters. Many a new design or invention has proved ineffective, not because it did not accomplish what was intended, but because some new feature, perhaps in itself trifling, has appeared which most provokingly makes the whole device inadmissable. Sometimes a change in some one feature increases certain elements which previously had been negligible and gives them an unexpected prominence.

The law of squares and the law of cubes is one source of disturbance. Double the linear dimensions of a transformer and its volume is eight times as great. If the internal losses increase in this ratio while the surface is only doubled and the distance from center to surface is also doubled, they may cause the internal temperature rise to increase accordingly in a higher power than is acceptable. Eddy-current losses, which may be negligible and unnoticed in certain apparatus, may produce quite conspicious results when dimensions of conductor, size of armature slot, induction density or frequency are changed. Windings whose mechanical strength has never been questioned succumb to the current which larger generators give on short-circuit, as is clearly shown by the remarks of Mr. Peck in this issue of the Journal. Similarly, fuses and circuit breakers after an unimpeached record for years of service have disappointed their designers when supplied with current from generators which are reasonably successful in maintaining their voltage on short-circuit.

The designer who is quite familiar with the use of insulating materials for use with apparatus of a few hundred volts may be quite oblivious to the problems which would confront him in 10 000-volt apparatus, and were he proficient in this field he might still be quite ignorant of the new difficulties to be encountered when another cypher is added to the voltage specifications. A new order of care is required when a few spoonfuls of moisture will vitiate a barrel of insulating oil.

A foresightedness which will indicate what will be the actual as well as the desired results is essential to the general engineer as well as to the designer. It is a most difficult matter to estimate all of the effects of a change in conditions, and trouble is most apt to come where it is unexpected.

It is unusual for a single cause to produce a single effect. Usually many causes combine to produce complex results. In applying certain apparatus or operations to new conditions it is no simple matter to recognize in what way some of them may act as new causes or to trace their effects to the final results. It is not only difficult to foresee effects, but it is difficult even to analyze and determine the true relations between causes and effects after the action has taken place and the effects have been produced. The quality of keen and unprejudiced observation is rare. Most of us are apt to have preconceived ideas as to what are the effective causes and are quite blind to others. The problem is particularly difficult when there are several contributing causes, as there is a tendency when one or two have been determined to conclude that they are the only ones. Every now and then there are instances in which the reason for some peculiar effect is finally found in some simple, unexpected place where it had been overlooked in the search for some complicated, "theoretical" cause.

But, the greatest test of constructive engineering is in predetermining the results which will follow from new causes and conditions. It calls for imagination, guided by a broad knowledge of scientific and engineering principles. These are the basis for foreseeing what new phenomena are apt to appear and for pre-estimating their effect. Hence, also the value of a habit of foreseeing things that one is not looking for. For these reasons the man who is equipped with a technical knowledge and a trained mind is apt to be the one who is best able to meet new and emergency conditions, provided the mind is trained to use the knowledge.

Chas. F. Scott

The Oscillograph

In the last issue of the Journal a very interesting example was given of what the oscillograph is doing in practical engineering work. This very important piece of apparatus is being more generally used every day. It is no longer looked upon as an interesting instrument fit for laboratory service only. Engineers are rapidly finding uses for it that give them new insight into the working of their machines. Old theories are being checked or disproved.

The instrument itself is more nearly like a galvanometer than any other piece of apparatus, differing from it principally in the periodicity of its moving parts, the oscillograph having a natural period of oscillation of several thousand per second. It is thus an easy matter for it to follow variations in wave forms that have a frequency of a thousand or lower. Its deflections, like those of a galvanometer, are indicated by the movement of a spot of light reflected from a small mirror. In order to separate the individual oscillations so as to present the appearance of a wave form showing the instantaneous values at various times, it is necessary to obtain a motion at right angles to the line of the deflecting spot of light. This motion for visual inspection is obtained by viewing the oscillating light spot as reflected from a revolving mirror. For permanent record, a photographic plate or film is moved rapidly past the light spot. An experienced operator is required in order to secure satisfactory results. The greater part of the difficulties lie in the manipulation of the optical system which is used in securing the reflected light spot. The instrument is connected into the circuit like a voltmeter or an ammeter, suitable resistances or shunts being used in the respective connections. Most oscillographs are provided with two or more independent oscillating systems so that they can be used for indicating the variations in two or more circuits simultaneously.

The current and voltage variations resulting from the blowing of a fuse, the opening of a circuit breaker, the discharging of a lightning arrester, the switching of transformers on high tension lines and many other momentary conditions, can be studied with an oscillograph better than any other way. It is also of equal importance in examining the wave forms of recurring phenomena. It is very frequently called upon in the diagnosis of serious cases of trouble and generally proves equal to the emergency.

S. M. Kintner

ALTERNATING-CURRENT GENERATORS—I

NOTES ON THEIR CONSTRUCTION. PERFORMANCE AND OPERATION

P. M. LINCOLN

THE general subject, Alternating-Current Generators, is too extensive to admit of exhaustive treatment in a limited article such as this must be. The following pages therefore make no pretense of exhausting the subject; they partake more of the nature of a series of notes.

Most of these notes are of a general nature and pertain equally well to alternators of any manufacturer. Where they are specific they relate to Westinghouse machines.

The notes are segregated into three general headings, viz:—

Construction,
Performance,
Operation.

The paragraphing indicates the general headings as well as the sub-headings into which they are again divided.

CONSTRUCTION

General Type—The standard alternators as at present built by all modern manufacturers are of the revolving field type. Revolving armature types are still manufactured, but only to supply the demand which was created before the merits of the revolving field type were as universally recognized as they are now. The merits of the revolving field type over the revolving armature type are, briefly, as follows:—

First. The revolving field type gives more space for the armature winding. For high potential machines this point becomes an important one.

Second. The insulation of the armature is relieved from the strains of centrifugal force.

Third. The number of collector rings is reduced to a minimum, viz., two; and the amount of energy to be handled by them is only about two per cent of that which would have to be transmitted through the collector rings of a revolving armature generator of the same capacity. The voltage on the collector rings is also relatively small.

Frame—Where a considerable demand is anticipated it is customary to lay out a complete line of machines, the contiguous sizes of which differ in weight by some fifteen or twenty per cent. The capacity of a given frame depends upon the speed, voltage and performance demanded by the conditions.

For the smaller sizes the frames are solid. Solid frames are used until an outside diameter of approximately eight feet is reached. Above this diameter the frames are split; this split construction being necessary because dimensions are limited by considerations of shipping and handling.

The main point to be looked after in alternator frames is a design that will give the maximum of rigidity. The only function of the frames of rotating field alternators is to hold rigidly in place the parts composing the stationary element. They perform no magnetic function. The frame is further designed with openings at the back of the laminations to give thorough ventilation. The manner of obtaining this ventilation will be described in a later paragraph. The frames contain dove-tailed slots into which the laminated iron for the stationary part is pressed. The laminated iron, however, carries all the magnetic flux and the frame is simply for the purpose of holding it in position.

Bed Plate and Bearing Pedestals—Alternators may be divided into three types depending upon the method of driving, viz: engine type, coupled type and belted type. In the engine type the revolving element is mounted directly on an extended engine shaft.

In the coupled type, as the name indicates, the alternator is entirely self-contained and is designed to be coupled directly to a prime mover, usually a water wheel.

In the belted type the alternator is self-contained and mounted entirely separate from the prime mover and connected therewith by a belt.

The almost universal practice is to make the bed plate, the individual bearing pedestals and the frame all separate. The parts are properly machined and bolted together. This practice enables the manufacturer to use the same parts for the various types of machines, and to vary the combinations of bed plate, bearing pedestal and frames to suit any case that may arise.

For some of the smaller belted machines a bracket bearing support instead of pedestal on a bed plate is used. This allows the size of the bed plate to be reduced to a minimum. This is general practice, however, only for the very smallest sizes of machines.

Stationary Armature—As indicated under the paragraph above on frames, the stationary armature is made by assembling the punchings into the cast iron frame. Each punching is supplied with dove-tailed projections which fit into properly milled and spaced dove-tailed slots in the frame. The punchings are separated at intervals by ventilating plates, which give opportunty for air to circulate freely through the ducts thereby created and out at the open back of the frame, as mentioned under the heading "Frame." Heavy end plates are supplied at both ends of the laminations so as to prevent their bulging out at the ends. Figure 1 shows a frame with the laminations and windings placed therein complete.

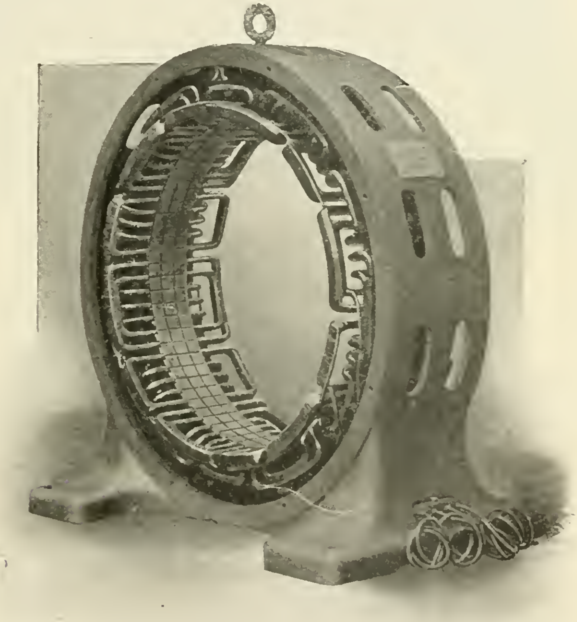

FIG. 1—VIEW OF FRAME AND ARMATUE WINDING OF A 200 KW ALTERNATOR

Terminals—Flexible leads are brought through the frame of the machine near the bottom and connected directly to the line or to terminal blocks which are mounted on the frame. The former arrangement is usually employed.

Rotating Field—The construction of the rotating field is very similar to that of the stationary armature except that the punchings are dove-tailed into a rotating spider instead of a stationary frame. The method of construction is well shown in Figs. 2 and 3.

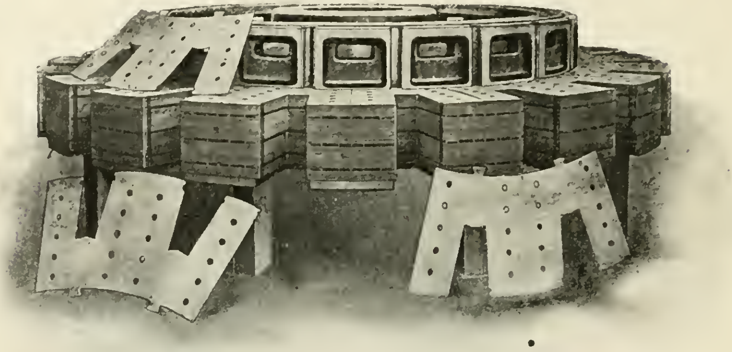

FIG. 2—VIEW OF LAMINATED FIELD CORE IN PROCESS OF CONSTRUCTION, SHOWING OVERLAPPING JOINTS, VENTILATING SPACES, ETC.

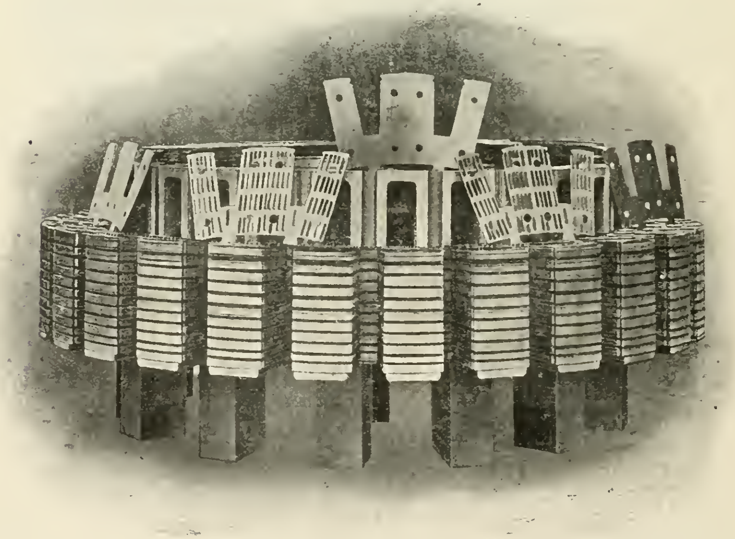

FIG. 3—VIEW OF FIELD CORE OF A REVOLVING FIELD ALTERNATOR IN COURSE OF CONSTRUCTION

Numerous ventilating slots are left through the rotating field as well as the stationary armature. Air circulates through these openings in the field and thence to the openings in the stationary armature, which register approximately with the field openings. Some air is also entrapped between the field projections and thence driven by centrifugal force through the armature ventilating slots.

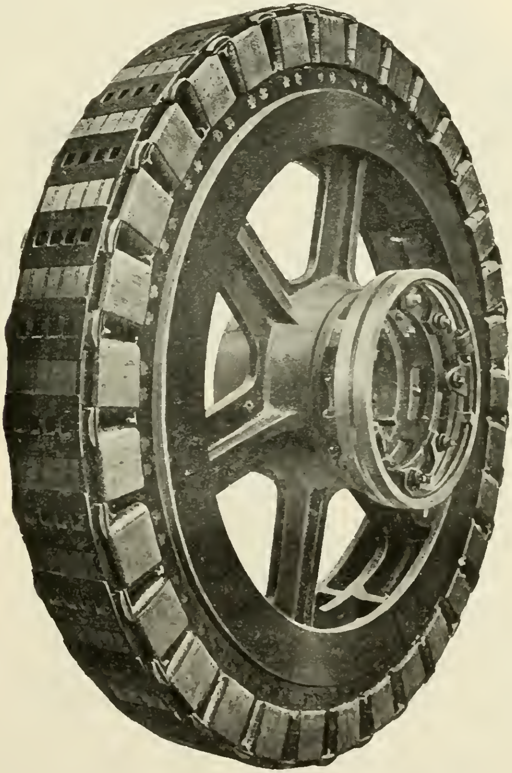

FIG. 4—VIEW OF REVOLVING FIELD SHOWING VENTILATED POLES AND DAMPERS. SUCH DAMPERS ARE USED WITH PARTLY CLOSED ARMATURE SLOTS

The field coils are wound to slip over the projecting poles and are held in position by wedges which are driven between the projecting poles into slots left for that purpose. This construction is shown plainly in Figs. 4 and 5. The wedges are made of copper and serve the double purpose of holding in the field coils and acting as dampers. As dampers they tend to prevent the setting up of hunting of alternators in parallel, or between alternators, synchronous motors and rotary converters. To meet special conditions it may become necessary to obtain a damping effect greater than that which can be obtained from the style of damper shown in Figs. 4 and 5. In these cases the grid damper shown in Fig. 6 is used. This is similar to the dampers used on rotary converters and is the most efficient form that can be applied. It is more expensive, however, than that shown in Figs. 4 and 5, and therefore is not used except where demanded by special conditions.

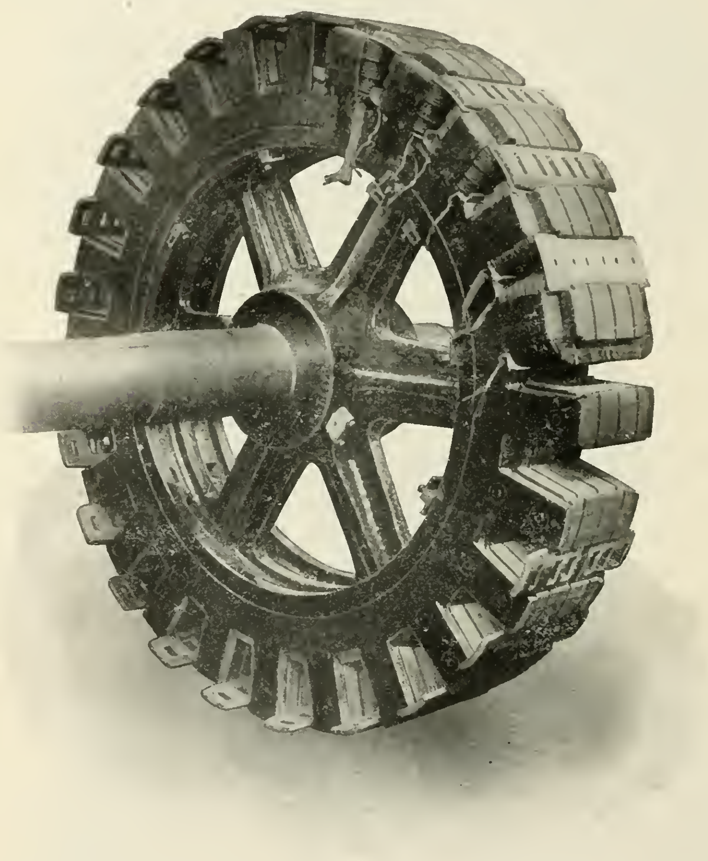

FIG. 5—VIEW OF REVOLVING FIELD, PARTIALLY WOUND. NOTE METHOD OF MOUNTING WEDGES WHICH HOLD THE COILS. WEDGES OF THIS STYLE ARE USED WITH OPEN ARMATURE SLOTS AND WITH SINGLE-PHASE ARMATURES

Small High-Speed Generators—A new form of field core has been developed for alternators of small capacity designed to operate at a high speed and having, in consequence, a small number of poles.

It consists of a solid steel casting forming the spider and poles, to which are bolted laterally projecting pole tips of solid steel which secure the coils and properly distribute the magnetic field. This construction is used for machines to which, on account of the wide

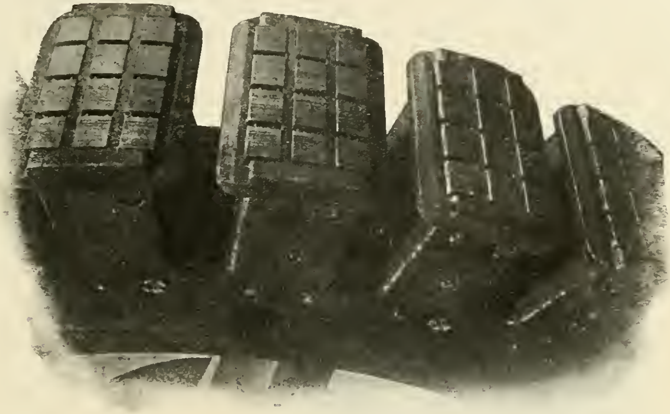

FIG. 6—VIEW OF SECTION OF FIELD CORE SHOWING POLES AND DAMPERS

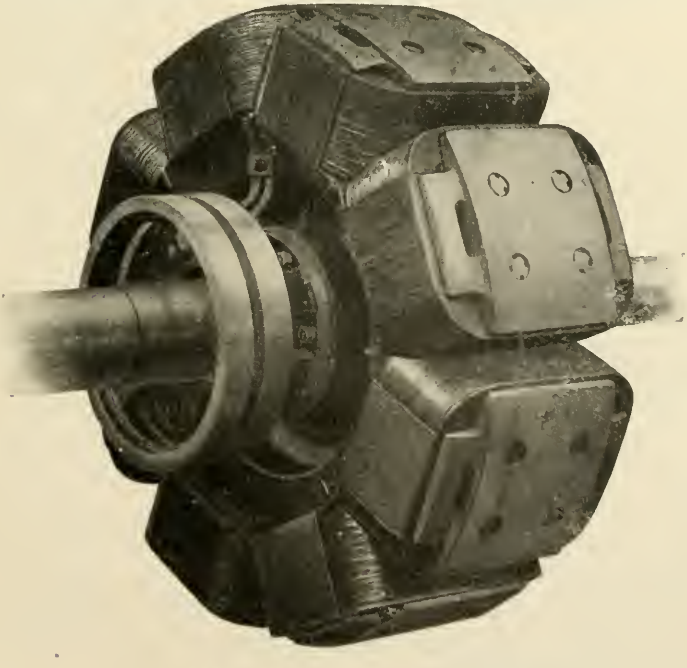

FIG. 7—REVOLVING FIELD WITH BOLTED POLES

distance between poles and the size of the coils, the laminated construction with coils secured by wedges is not well suited. This method of construction is shown in Fig. 7.

Field Coils—The field coils are wound up in moulds. Wire is used for the smaller generators and in those of larger capacity copper strap bent on edge is usually employed as shown in Fig. 8. The strap wound coils are insulated between turns with asbestos strip forming a fire-proof coil which is practically indestructible. The wire coils are wound dry and treated with insulating varnishes. In every case the insulation provided is easily sufficient for the low e.m.f. to which the field winding is subjected.

The coils are held together by cord or rope and have no metallic bobbins or hangers. The winding is therefore in direct contact with the air and thus has good heat radiation.

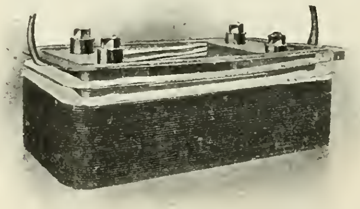
FIG. 8—STRAP WOUND COIL READY FOR INSULATION

Excitation—Alternators are usually separately excited by 125 volt direct current. This e.m.f. is generally regarded as standard, is easily handled and lends itself readily to the operation of lights and small auxiliary machines in power stations. For large alternators two hundred and fifty volts has frequently been employed and field coils can be wound for this potential when required. The lower e.m.f. is generally to be preferred principally because it permits the use of strap-wound field coils. For generators large enough to employ field coils of this type at the higher e.m.f., 250 volt excitation is not objectionable. The limitation comes in the fact that very thin copper strap cannot be successfully bent edgewise.

Composite Winding—When employed with revolving field generators a composite winding is usually obtained by the use of separate transformers of the series type connected in the armature circuit with secondaries connected to a separate field winding through a rectifying commutator mounted on the generator shaft. This subject is also touched on under the subject of "Regulation." The diagrams, Figs. 9 and 10, show one method of connection for compounding alternators.

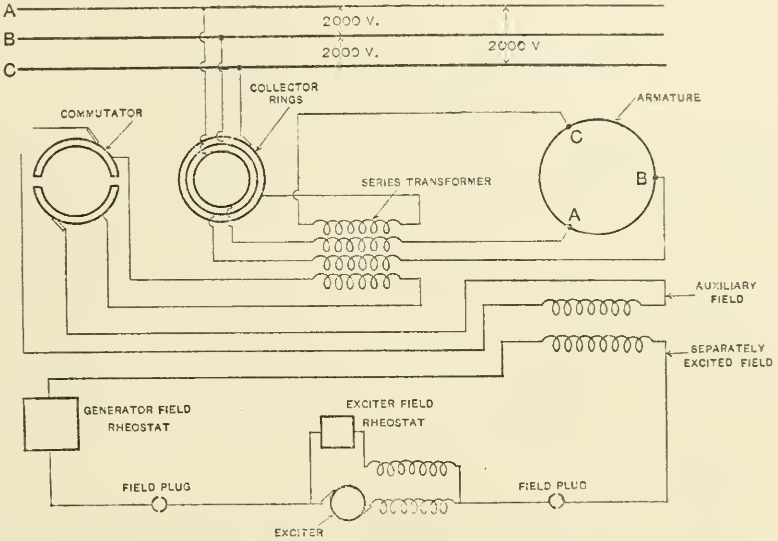

FIG. 9—DIAGRAM OF CONNECTIONS FOR A COMPOSITE-WOUND THREE-PHASE

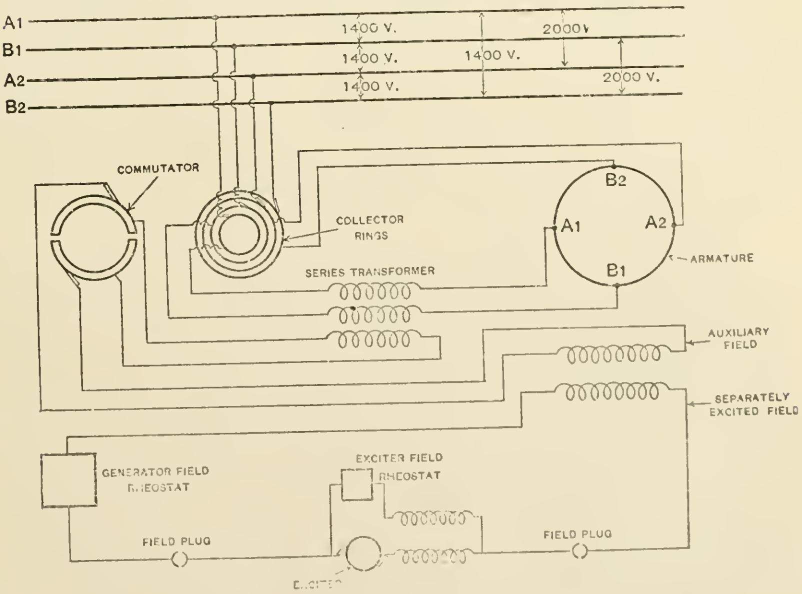

FIG. 10—DIAGRAM OF CONNECTIONS FOR A COMPOSITE-WOUND THREE-PHASE GENERATOR

(To be continued.)

DISCOVERY AND INVENTION*

EDWARD GOODRICH ACHESON

President, The Acheson Company, Niagara Falls, N. Y.

THE invitation to appear before you was presumably given on the assumption that I would speak upon some subject interesting to you as engineers and having relation to my own work, one to which I might, perchance, add points of value or interest over and above that obtainable from the public storehouse of knowledge. After giving the subject considerable thought, I determined on confining my remarks to Discovery and Invention, as closely related to my life work, preluding the references to personal work with a brief glance at a few noted examples of Discovery without Invention; Invention without Discovery; and Discovery with Invention.

Discovery—The act of finding out or of bringing to knowledge what was unknown; first knowledge of anything—is usually without meditation, it is accidental; true, the finder may be engaged in a search for conditions of things of the general nature of the discovered, but it would not be a discovery did he know or have reason to believe it existed under the conditions or in the place he found it. He may be likened to the traveler who casually picks up a rough, uncut gem. The inventor is the lapidary who finds a use, a place for the gem. It is he who with labor, care and expenditure of grey matter polishes and beautifies the rough stone. His work is to create, not simply to find.

In 1831 Michael Faraday while trying to find a constantly flowing current in a wire lying beside and parallel to another wire through which a current of electricity was flowing, noticed when the wires were coiled upon an iron ring that a momentary kick or swing of the needle of the galvanometer to which the dead wire was attached occurred upon opening or closing the circuit through the live wire. He followed up these observations with experiments extending over a period of ten days, and on the 29th day of November. 1831, while at Brighton resting from his labors, wrote his friend Mr. R. Phillips as follows: "We are here to refresh. I have been working and writing a paper that always knocks me up in health, but now I feel well again, and able to pursue my subject; and now

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*A lecture delivered at Massachusetts Institute of Technology, March 9, 1906, and at Sibley College of Mechanical Engineering, Cornell University, May, 1906.

I will tell you what it is about. The title will be, I think, 'Experimental Researches in Electricity.' I. On the Induction of Electric Currents. II. On the Evolution of Electricity from Magnetism. III. On a new Electric Condition of Matter. IV. On Arago's Magnetic Phenomena. There is a bill of fare for you, and what is more, I hope it will not disappoint you. Now the pith of all this I must give you very briefly, the demonstrations you will have in the paper when printed."

Such was the simple, homely language used by this truly great man in referring to one of the most momentous discoveries of the ages. Faraday made this discovery at the very close of the fortieth year of his life; he died in 1867, or thirty-six years after that eventful period, crowned with great honors for his scientific investigations, and yet without having witnessed the remarkable applications to the world's industries, wealth, and, shall I say, happiness, of the great fact of electric induction which he had discovered. For something like forty years it awaited the inspiring touch of invention. To-day we have with us the telephone, the electric light, the electric railway, and many more necessities and conveniences that were only made possible by this discovery of Michael Faraday. This I take to be an apt illustration of Discovery without Invention, that is to say by the discoverer.

Another illustration of Discovery without Invention is, I believe, to be found in the history of the telephone. Without wishing to detract in any way from the honors of Prof. Alexander Graham Bell, to whom the world to-day is greatly indebted, I believe this very valuable invention, if it now existed as or consisted of the parts as produced and left by him, would be practicably a toy, truly a very interesting one, but incapable of the marvelous use to which it is now put. His keen observation recognized that a disc of iron caused to approach and recede from a magnet in consonance with the air waves of spoken words, would produce currents of electricity in a wire surrounding the magnet, varying in intensity with the air waves moving the disc, and he further discovered that these electric currents, when made to pass around a second and similar magnet having a like disc of iron in close proximity to its end, caused the disc to move and buckle in response to the currents and thereby produce air waves like the original ones and consequently articulate speech. It required the inventive genius of Edison, Dolbear, Blake, and others to put this discovery into the commercial forms of to-day.

An illustration of Invention without Discovery is shown by the great invention of Sir Henry Bessemer in 1856. This consisted, as you know, in blowing air through melted cast iron, thereby burning out the carbon and converting the metal into a malleable product. For this he was made a Fellow of the Royal Society and received knighthood in 1879.

Some years ago it was customary and necessary to employ expert telegraphers to pick up a message from one wire and transmit it to another one where long distances were covered. In one of the repeating offices situated in the Middle States was a young expert operator by the name of Thomas Edison. One day, or night, one of his superiors at the office entered the room and found young Edison sound asleep, while a small inanimate instrument was industriously performing his work, (the great Edison repeater) performing it even better than Edison personally could have done. Shortly after this unheard of neglect of duty Edison was looking for another job. This was certainly a beautiful example of applied known principles. Much to the advantage of the world, Edison's inventive genius was not daunted by this rebuff. By his quadruplex system, he practically quadrupled the capacity and value of the telegraph wires of the world.

The development of the telephone above referred to, likewise the electric light and many other instances that will occur to you, are cases of Invention without Discovery.

Discovery with Invention is strikingly illustrated by the work of Charles Goodyear. The life of this remarkable man is most interesting, and feeling sure that it will meet with your approval, I venture to quote from the National Cyclopaedia of American Biography much of the following history.

Charles Goodyear was born December 29th, 1800. His father was in the hardware business at New Haven, Conn. When still a young boy he one day picked up a scale of India rubber that had peeled from a bottle. He at once conceived the notion that it would be very valuable if it could be made uniformly thin and rendered free from cracking, sticking, and melting with variations of temperature. When he reached his majority he entered into partnership with his father. In 1826 he went to Philadelphia to represent his firm. Four years later they failed in business, and during the succeeding ten years he was repeatedly imprisoned for debt. In 1831 he became again interested in his rubber project. Strenuous effort had been made by others to cure rubber and make it serviceable as a fabric, and to that object he now devoted his life. He met with no real encouragement of success for the first four years of his investigations, which were not seldom carried on in prison. He became at last the butt of those who could not share his faith. He remained calm, patient, assured of ultimate and lasting success, he and his family literally living from hand to mouth, sometimes selling his children's books and pieces of household furniture to meet the calls of hunger. In the early months of 1839 relief came in his discovery of a process by which high degrees of heat applied to rubber, which had been coated with sulphur, brought about the vulcanization of the raw material, so that it kept elastic in all temperatures. Before his death, which occurred July 1st, 1860, he saw vulcanized rubber applied to nearly five hundred different uses, and sixty thousand people engaged in making the articles into which it was fashioned. It has been said, "No inventor, probably, has ever been so harassed, so trampled upon, so plundered by pirates as he—their spoliations upon him having unquestionably amounted to millions of dollars."

Before touching upon my own latter work, I wish to reminisce a little, and trust what I may say will be found sufficiently interesting to justify detaining you and illustrate the possibilities before a young man.

Leaving an academy in 1872 in my seventeenth year, I became a time-keeper at a blast furnace; I later joined a civil engineer corps on railroad construction; then I was ticket clerk on a railroad; again I was at civil engineering on a railroad; then I measured and computed the capacities of oil tanks in the oil country; then I was for a time book-keeper; then I mined iron ore for a living, and on the first day of September, 1880, I left Western Pennsylvania for my first trip to New York City with the avowed intention of obtaining electrical work. The twelfth day of the month saw me located with Mr. Edison at Menlo Park as assistant draftsman. Within a few weeks I had formed the personal acquaintance of Mr. Edison and was moved from the drafting room to the original Experimental Department. In the following winter Mr. Edison, who was strenuously endeavoring to find the best material for the filament of his lamp, directed me to experiment upon the production of a filament of graphite. He encouraged me by promising me a prize of $100.00 when I succeeded in making a flat loop of graphite measuring one inch outside diameter, the filament to be twenty-five thousandths wide and two-thousandths of an inch thick, the same being capable of mounting in a glass globe.

With proper facilities for purifying the graphite, hydraulic press for pressing sheets and dies for cutting out the loop, I made, I think, about 16 000 of these filaments, having succeeded in making them one-half what was requested by Edison, or one-thousandth of an inch thick.

You will certainly think that I was a "rolling stone," and I can assure you that there was no "moss" on me, of the kind that passes current on Wall street. On the 20th of the following July I sailed out of New York harbor as first assistant engineer for the Edison interests at the Electrical Exposition in Paris. I had the pleasure, sometimes, and the undoubted honor, always, of installing the first commercial incandescent lighting plants in Holland, Belgium and Italy.

You will note that in this brief history no mention is made of higher education. I was frequently thrown with college bred men, prominent among whom I would mention particularly, Dr. Edward L. Nichols, now Professor of Physics at Cornell University, whom I found with Mr. Edison at Menlo Park when I went there in 1880. A strong and lasting friendship sprang up between us, and I greedily absorbed what I could of the knowledge he freely parted with.

In the latter part of the year 1880 I had brought to my attention the value of an abrasive material by a remark incidentally made by Mr. George F. Kunz, of Tiffany & Company, New York. While making some experiments in 1886, I passed a quantity of hydrocarbon gas over highly heated clay, and observed that the clay became impregnated with carbon, and I thought it was increased in hardness by the presence of the carbon. In the early part of the year 1891, having at my command an electric generating plant of considerable capacity, and looking about for a line of experiments I thought to try the impregnating of clay with carbon under the influence of the high heat obtainable with the electric current.

I mixed together a quantity of clay and powdered coke, placed the mixture in an iron bowl such as plumbers use for holding their melted solder. Into this mixture I inserted one end of an electric lamp carbon, the other end being connected to one lead from a dynamo, the other lead being attached to the iron bowl. A good strong current was sent through the mixture until the central portion of the clay was thoroughly melted. When cold the mass was removed and examined carefully. Adhering to the end of the carbon rod I noticed a very few small bright specks. With difficulty I secured one and placing it on the end of a lead pencil, drew it across a pane of glass. It not only scratched but cut the glass. I had found the rough, uncut gem.

Appreciating the possible value of my discovery, and notwithstanding the exceedingly minute quantity of crystals produced, I undertook further experiments, and if I am not mistaken, two months or more had passed before I had enough crystals to fill a small vial measuring about three-eighths of an inch by one inch Naturally I early undertook to prove its value as an abrasive. I mounted an iron disc in a lathe, charged its surface with oil and my new, then unnamed product, and with this revolving disc cut the polished face off this diamond on my finger. (You may appreciate why I wear it and hold it at a value much above its commercial worth.)

Having filled my little vial, I placed it in my vest pocket and went to New York where I had a diamond cutter use some of my new material for the re-polishing of my diamond. I had named it while on the way to New York. I called it carborundum under the belief that it contained carbon and corundum. The diamond cutter bought what was left of the material at the price of 30 cents per karat, and with the proceeds I purchased a microscope to assist me in the further study of the material.

Soon after this I learned that it was the silica in the clay and not the alumina that was associating itself with the carbon, and before long I had quit the use of the clay, having substituted sand.

I had devised an electric furnace in which a resistant material formed a central core around which was placed the material to be heated, and this probably was the first furnace wherein thermal and chemical effects were produced within the mass of material operated upon, the outer portions of the mass acting as retaining walls. It is thus that we can work at higher temperatures than would be possible were we required to depend upon the furnace walls proper.

The history of the development of carborundum is overflowing with trial, tribulations, and glorious triumphs. In 1894 The Carborundum Company, a company I had formed to develop the business, was located at Monongahela City in Western Pennsylvania, and it was operating a steam generating plant of 134 horse power. The cost of production was so high that the trade was restricted to lapidaries, valve grinding, and kindred lines that could afford to buy it, and but one-half its production was sold. The new electrical development at Niagara Falls was at this time approaching completion. I went to Niagara Falls, looked over the situation, possibilities and prices. On my return I convened a meeting of my board of directors and laid before them a scheme of moving to Niagara Falls and there building and equipping a plant for 1 000 horse power.

To build a plant for 1 000 horse power, in view of the fact that we were only selling one-half of the output from a 134 horse power one, was a trifle too much for my conservative directors, and they one and all resigned, arose, and left the room. Fortunately I was in control of the destinies of The Carborundum Company. I organized a new board, proceeded with my plans, and in the year 1904, the thirteenth one from the date of the discovery, The Carborundum Company had a plant equipped with 5 000 electrical horse power, and produced over 7 000 000 pounds of those specks I had picked off the end of the electric lamp carbon in the spring of 1891.

It has been held as an opinion by some that my work on carborundum was simply an extension and development of the work of P. Schutzenberger, and in this connection I wish to say that some time after I had made my original experiments on carborundum and knew the substance to be the compound SiC, I learned that Schutzenberger had produced such a compound. On investigation I found he had communicated to the Academy of Sciences of France on Monday, May 16th, 1892, the results of his work under the title "Contribution to the History of Carbo-Silicon Compounds". This communication was made some three months later than the date on which Mr. Nikola Tesla exhibited a lamp containing carborundum (which I had made and furnished him) before various scientific societies of Europe. Furthermore, Schutzenberger describes his experiments as having been made with a mixture of silicon and silica plaçed in a bone-black crucible, the latter covered with a lid of like material and embedded in lampblack contained in a larger crucible; this again being embedded in a third crucible. The nest was placed in a furnace brought up to a high heat and retained there for some hours. Upon cooling and opening, the contained silicon was found to have been changed to a green substance, and to have gained in weight an amount equal to one-half of its original weight, the silica remaining unchanged. An analysis showed the green material to be carbide of silicon with the formula SiC. You will notice the silica remained unchanged, consequently his work had no relation to mine nor mine to his. I started with silica, reduced it and formed the carbide. He does not mention the formation of crystals, and I am persuaded that he did not make any carborundum.

Some years ago I discovered that when carborundum was heated to a very high temperature, decomposition occurred, the contained silicon was dissipated in vapor and a beautiful graphite left as a pseudomorph, or as I was pleased to call it, a skeleton of the original carborundum crystal. This discovery started me on a new line of thought, and as a result of a long series of experiments, the present methods of the International Acheson Graphite Company, a corporation I formed to carry on the business, were perfected.

The development of the business has been phenomenal. The products of this company in the form of rods, bars and plates are extensively used by the electrochemical and electrometallurgical industries, almost to the entire exclusion of amorphous carbon, which they formerly used, not only in America but throughout Europe. In the pulverized form, it is used extensively as a filler in dry batteries. It is rapidly growing in favor for stove polish, lubrication, foundry facings, and as a paint pigment. It is particularly well adapted for paint, being a very pure form of carbon, free from oxides and readily reduced to a very fine powder.

It is possible to produce practically chemically pure carbon by our methods, but the cost increases as this condition is approached, and for commercial purposes the purity of 99.5 per cent. is adopted for electrodes for use in electrochemical and electrometallurgical work, while for the paint and kindred uses 97 per cent is the standard. When it is remembered that a good quality of natural graphite containes but 85 per cent. carbon, while most of that sold in the market runs as low as 45 per cent., it will be appreciated that our product is unique. For electrical work it is almost ideal. A rod or bar of this graphite is graphite throughout. It is not made up of small graphite particles held together by a binding agent; it can be cut, planed, tapped and threaded like a metal; its electrical conductivity is about four times that of a similar sized rod of amorphous carbon. Its rate of disintegration in electrochemical work is very slow. In some lines of work it lasts twelve times as long as amorphous carbon.

I early hoped to introduce my newly made graphite into the crucible trade, which I knew to be a large user of the natural product. It was found to be too porous, offering too large a surface for oxidation, and my experiments on this line were not productive of success. Mr. Edison used to tell me every experiment had its value. It either accomplished the result sought for or it taught you what lines to avoid. My failure to make a successful crucible of graphite put me, so to speak, on my mettle, and from then on I was on a constant watch for a suitable material, and I now hope and believe I have found one capable of making a better crucible than either graphite or clay.

The International Acheson Graphite Company now has a plant equipped with 3 000 electrical horse power, and during 1905 produced 2 385 123 pounds of graphite electrodes, and 1 870 411 pounds of what is termed bulk graphite, made principally from anthracite coal.

Before leaving the subject of graphite, I desire to recognize the extensive work of Prof. Henri Moissan. While in America some years ago he called on me at Niagara Falls, and I had the pleasure of conducting him through the plant of The Carborundum Company. I was at that time already engaged on my graphite work, and I remember with what apparent surprise he viewed the large amount of graphite I had produced artificially, his own work, as you know, having been of a laboratory or experimental nature.

Prof. C. F. Burgess, in a paper read at the eighth general meeting of the American Electrochemical Society, September 20th, 1905, stated that the study of the operation of the carborundum furnace led to the discovery of a compound of oxygen, silicon and carbon, and that this compound, previously unknown, was named siloxicon. The professor was apparently not in possession of the facts of the case, which are as follows:

During the latter part of the summer of 1899, I became interested in the direct reduction of silicon and one of my early experiments was to intimately mix, in fact, rub together fine, soft, pure graphite and silica, so proportioned as to provide the necessary carbon for the reduction. The quantity, distribution, and conductivity of the graphite was sufficient to carry the necessary current. After the current had been passed for some time, the furnace cooled and opened, a small quantity of metallic silicon was found disseminated in and held as distinct particles throughout a loose bulky mass of a greenish grey substance. The loose fluffy character of this material, together with the knowledge that it had been formed or at least existed in the path and at the temperature of the reduction of silicon caused me to immediately recognize the fact that it was what might be termed a highly refractory body.

I looked upon the possible value of this newly discovered material as perhaps greater than the metallic silicon I had produced, and it was it that thereafter received my attention. Patents were, however, applied for on a direct reduction of silicon, and the right to manufacture under them was sold to The Carborundum Company under date of July 5th, 1901, and since then they have been working on this problem under the direction of their works manager, Mr. F. J. Tone.

This discovery was followed by much analytical and experimental work. The substance was found to be composed of silicon, carbon and oxygen of varying proportions, a typical formula being Si_2C_2O. It was found to be amorphous, inert to both acid and basic slags, insoluble in melted iron, self-bonding when pressed tightly together and heated to about 2500 degrees F. and absolutely infusible, its inevitable destruction occurring as decomposition at a very high but as yet undetermined temperature, the silicon, oxygen, and a part of the carbon passing away as vapor or gas, while a part of the carbon remains as graphite occupying the space of the destroyed body, which I have named siloxicon from the words silicon and oxygen.

The Siloxicon Company, which I incorporated in 1903, is now engaged in developing the prospective business in its line, confining itself, however, to the manufacture of the crude siloxicon.

As an agent for the experimental work, development and exploitation of the detailed manufacture of siloxicon in finished articles such as crucibles, muffles, bricks, etc., I incorporated the Acheson Siloxicon Articles Company, and it is now actively at work upon the problems falling to its lot.

Probably never before was the world so prepared to accept and utilize a discovery, never before so ready to listen to, help and protect the inventor.

Undoubtedly many of you will be called upon to do experimental work, to investigate the unknown. If nature has not equipped you for the work of a Goodyear, uniting in you the faculties of a discoverer and inventor, be a Faraday, a discoverer, or a Bessemer, an inventor, but let me warn you, impress upon you with all the force possible, to avoid the ways of the pessimist. You will scarcely succeed if you fall in with his methods of thought. If, without previous information, you were told that it was proposed to cut into a metal plate 48 000 distinct, perfect, parallel lines per lineal inch, and that with this plate it was proposed to break up a beam of white light into the most perfect and beautiful of spectrums, what would you say? How many of you would predict failure; declare it absolutely impossible of attainment? And still these things were done by our late countryman, Prof. Henry A. Rowland. Some time ago I visited the Johns Hopkins University, and while there was conducted down into a subterranean vault where, free from rapid or great changes of temperature, was the marvelous ruling machine invented by Prof. Rowland for making his gratings. Set in the brick wall of the vault was a bronze tablet bearing the name and dates of birth and death of Henry Augustus Rowland. I was told that back of this tablet had been placed the ashes of this remarkable man. Here in close proximity to his master-piece, was the final resting-place of the earthly tenement of this master mind.

It is interesting and instructive to study, and analyze the mental make-up of the discoverer, the inventor, and one uniting the qualities of both.

Faraday was an optimist, was remarkable for a vivid imagination. He had the knack of seeing minute quantities, small things that would escape the observation of the ordinary man.

Edison, as his works illustrate, clearly appreciates the possible value of the new, of a new arrangement of parts, a new application of old or new principles. He is overflowing with faith in his being able to accomplish desired ends. He sets up an objective point and with indomitable energy and perseverance strives to reach it.

Goodyear combined the dominant qualities of Faraday and Edison. As a young boy his imagination pictured the sticky rubber converted into a serviceable form. He later dedicated himself to a fixed purpose. Having mixed up a little rubber and sulphur with the hope of improving the former, and not obtaining the desired end, he cast the failure into the hot ashes under the fire in his room. Later, by accident, this rejected evidence of another failure came into his hands, and was, to his surprise and undoubted delight, found to have the qualities he had for four long years been vainly hunting for. Thus he discovered that a mixture of rubber and sulphur, subjected to the heat of the hot ashes, cured or vulcanized the rubber and made it elastic at all temperatures. He evidently appreciated the commercial worth of the discovery, and witnessed the marvelous development and applications during his life.

In my own work I have been so fortunate as to have repeatedly turned failure into success. In the debris of the melted clay and carbon mixtures, which proved a failure for the purpose I had in view, my attention was riveted on the unexpected bright specks. The present size of the carborundum industry indicates my appreciation of the possible value of this discovery. Again it was not the small quantity of metallic silicon I made in my experiment in 1899 that interested me most. True, it furnished evidence of my theories of the possible reduction having been correct, but I realized that the loose, bulky material I discovered occupying the major part of the furnace might prove vastly more valuable.

Reviewing this sketch, I would sum up the dominant qualities determining the success of the discoverer and inventor to be: 1. Optimism. 2. Imagination. 3. Observation of small things. 4. Appreciation of the possible value of the new. 5. Knowledge of the existing art. 6. Self-reliance. 7. Having the determination to attain an end. 8. Indomitable perseverance, and I might add a 9th, (valuable particularly to the inventor) Proper assistance. My own work has been so varied and extensive, it would have been difficult to accomplish had I not received earnest, loyal, and valuable support, and from no one did I receive this more fully than from Mr. F. A. J. Fitzgerald.

In conclusion, I would say I hope and believe you all have ample time, with due energy, to accomplish great things. Hanging on the wall of my office is an engraving from the photographs of the so-called "Captains of Industry," the gentlemen who, by invitation, met H. R. H. Prince Henry of Prussia at breakfast in New York, February 26th, 1902. I have been able to consult short biographia of seventy-six of these "Captains" and I find but seventeen of them are under fifty years of age, only three being under forty years of age, and that their average ages were 57.5 years. You may be further interested to know that no less than thirty-seven of these seventy-six gentlemen had not had the advantages of a college education; they are what are popularly called self-made men.

THE INFLUENCE OF LOAD FACTOR AND PRIME MOVER CHARACTERISTICS ON POWER STATION ECONOMY

J. R. BIBBINS

POWER station economy, although usually regarded as a more or less invariable quantity under certain operating conditions, is subject to a host of influences tending to the production of abnormal results; in fact two power stations similarly equipped and in the same service might very readily show wide differences in final operating results due to causes apparently significant, but actually operating to disturb the normal working of the equipment. And in endeavoring to draw just comparisons between the operating economy of various power equipments in various classes of service, even a superficial study will disclose the fact that unless definite and similar conditions surround the respective figures, a comparison would be apt to be misleading. That all such data should be referred to a definite standard will be apparent from the following discussion based upon views recently set forth in the transactions of the American Institute of Electrical Engineers, February, 1906. Only the two most important influences may be taken up here, viz., engine characteristics and load factor.

HEAT ENGINE CHARACTERISTICS

As the saturation and regulation curves of a dynamo are characteristic of its operation, so do certain curves as definitely characterize the working of a prime mover. Speaking particularly of heat engines, there are three curves which materially assist in determining the suitability of a machine for a particular service; these curves represent:—

1. The hourly heat (steam or gas) consumption at various loads with its derived curve of the "water-rate" variety familiar to steam-engine practice.

2. Kinetic (absolute thermodynamic) efficiency, with its derived curve of mechanical efficiency.

3. Speed regulation, involving, in the case of the reciprocating-engine, cyclical as wel as absolute speed-variation.

The first determines the rate of input of working medium steam, gas, air, etc.; the second, the efficiency of conversion into useful work in the shaft; and the third, the suitability of the machine for operating constant-potential electrical apparatus. In this discussion we are chiefly concerned with the first, and from a purely practical standpoint.

Steam-Engines—In high-speed steam-engines such as the Willans, governing by throttling steam-pressure, the total steam consumption per hour is practically proportional to the load. Plotted in the form of a curve, known as the "Willans"* or water line, it gives practically a straight diagonal line *A B*, Fig. 1.

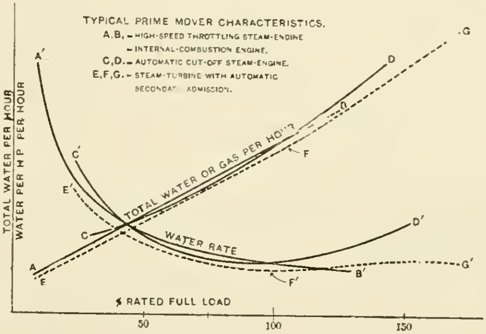

FIG. I

The so-called water-rate curve derived from this, *A′ B′*, and expressing steam used per horse power per hour is then, of course, an hyperbola and shows a constantly decreasing water-rate with increasing load. Clearly, then, this type of engine is able to give its best economy at maximum output. In modern power work, however, this condition is demanded only occasionally to tide over maxima in a fluctuating load; on the other hand, from an economical standpoint, the engine is obliged to work at considerable disadvantage during normal loading.

Now in a steam-engine governed by a positive cut-off, the water-line is decidedly curved, *C D*, due to a variety of causes, giving a water-rate curve *C′ D′* of more pronounced curvature. Two important results have, however, been achieved; first, the engine gives its best economy between three-fourths and full load where it is normally working a greater part of the time; and secondly, by lengthening the cut-off a very large overload capacity is available. On the other hand, the cut-off method compares less favorably at light loads and heavy overloads, the water-rate increasing rapidly in either direction.

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*"Willans Law" first expounded by P. W. Willans. See Transactions British Institution Civil Engineers, 1890.

Steam Turbines—Manifestly a combination of the two systems should yield the characteristics most to be desired; these characteristics are:—

(*a*), maximum economy at normal loading;

(*b*), large overload capacity with fair economy;

(*c*), good economy at light loading. These have fortunately been realized to a large extent in the steam-turbine.

A steam-turbine of the well-known pressure type gives a practically straight water-line, *E, F,* Fig. 1, up to about full-load with a somewhat higher inherent efficiency than the steam-engine, in most cases exceeding the cut-off engine even at the best load. By the use of a "secondary" admission of steam to lower stages in the turbine, its power may be increased to as high as double the normal rating and with but small loss in economy. Supposing the secondary or overload valve comes into action about full load, *F*, the water-line changes direction, *F G*, resulting in a compound water-rate curve, *E′ F′ G′*. At the point of opening, *F′*, the steam consumption begins to increase, but as the overload increases the turbine tends to regain its original efficiency. Furthermore, the prime mover and generator are better matched in regard to efficiency than in the cut-

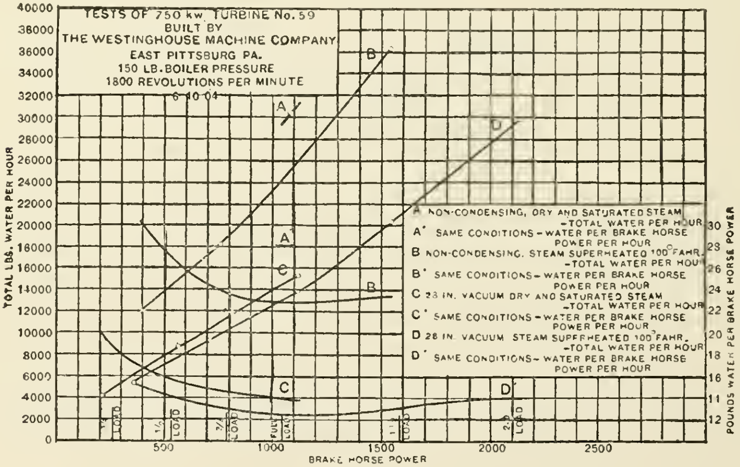

FIG. 2

off engine, both doing their best work at normal rating.

These characteristics are well illustrated in the accompanying curves, Fig. 2, showing tests upon a 1 000 hp Parsons' type turbine. From one-half load to 100 per cent overload the water-rate varies but little over ten per cent. The same characteristics appear in the non-condensing tests, except that the turbine was unable to sustain as heavy a load, being guaranteed only for full load non-condensing and 50 per cent overload condensing.

Low-Pressure Turbine—If we represent in curve form, Fig. 3, the work available in steam expanding from 150 lb. initial pressure to atmosphere, the fact is apparent that there has been used only about one-half of the total work available at a vacuum of 28 in. This at once explains the possibility of the low-pressure steam-turbine working on vacuum alone, and it is interesting to note that the water-rate of such a turbine is about double that of a similarly constructed turbine working through the entire range of pressure. Thus a 750-kw Westinghouse-Parsons turbine below atmosphere has given a water-rate of 25 lb. per brake horse power with high vacuum, corresponding to about 13.5 lb. brake horse power-hour for the total pressure range. Moreover the total water-line is practically straight as in the normal turbine showing that steam is used with uniform efficiency at all loads. Professor Rateau of Paris has done much along these lines of low-pressure turbine work. The low-pressure turbine is of interest in providing a means of nearly doubling the output of a non-condensing steam plant with but little increase in operating expense. Cooling-towers are, of course, of assistance where water is costly.

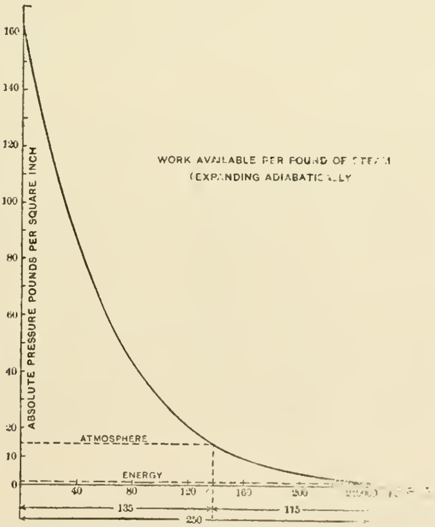

FIG. 3

High-pressure turbines, working down to atmospheric pressures, are, on the other hand, frequently used in district heating systems, half of the energy in the steam being converted into electrical energy, and the remainder into heat. Usually, a condensing turbine is employed running non-condensing during cold, and condensing during warm weather.

Internal-Combustion Engine—Curiously enough, the gas-engine presents the same characteristics as the throttling steam-engine; namely, a nearly straight Willans or gas-line, *A B*, Fig. 1, and a continually decreasing rate curve of gas consumption, *A′ B′*. It possesses, however, nearly double the efficiency of heat conversion or kinetic efficiency * of the steam-engine. An engine of good design is capable of delivering from 25 per cent to 30 per cent of the heat of the gas in the form of work at the shaft, while the corresponding kinetic efficiency of a large steam-unit usually runs from 12 per cent to 15 per cent and of a steam-turbine 15 per cent to 22 per cent of the heat input. As a machine, its mechanical efficiency is nearly the same as a high-grade reciprocating steam-engine.

Could we rate the gas-engine at its maximum capacity we should, of course, obtain maximum efficiency at normal rating, and in European practice this is frequently done; but in American practice some overload capacity is demanded, hence we must deliberately rate the engine below its maximum by the per cent of overload desired. This is an unfortunate characteristic of the gas-engine; that its maximum power is reached when the cylinder is full of mixture, and it seriously militates against gas power in the minds of those who follow a more or less universal custom and install a smaller steam-engine with the deliberate intention of overloading it.

LOAD FACTOR

The above discussion leads up to the recognition of load factor as an important element in any expression of the operating economy of a power station. The term load factor is often used indiscriminately and in widely varying sense. True load factor expresses the ratio between the average and the maximum load.

$$\text{Load factor} = 100 \, \frac{\text{Kw—hrs. generated}}{\text{Maximum kw} \times \text{hrs. run}} \, \%$$

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*Kinetic efficiency is defined as:— $\dfrac{\text{Thermal equivalent of useful output}}{\text{Total heat input in gas}} = \dfrac{2545}{\text{B. t. u. per brake h.p.—hr.}}$

This quantity shows how nearly the station load approaches, that which would be most ideal for engine operation, viz., full load. Quite frequently the ratio of average load to generating capacity in service is termed load factor or even the ratio of average to total rated capacity of station. For distinction the former may be termed loading factor and the later station loading factor. The expression,—

$$\text{Loading factor} = \frac{\text{Average load}}{\text{Rated capacity in service}}$$

evidently approximates true load factor in cases where no great amount of reserved capacity is available, and where the entire capacity of the plant is necessary to carry peak loads. It is also of importance in properly proportioning or "blocking in" engine capacity to suit a particular load curve. For example, Fig. 4

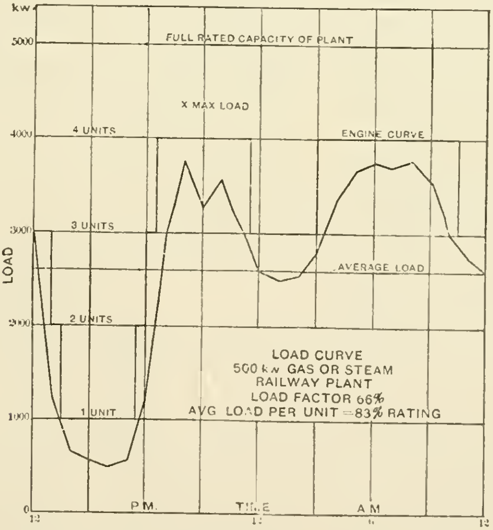

FIG. 4

represents an actual 24 hour station load curve from a large city railway system. Given this load, the proper engine capacity may easily be "blocked in" as shown by the engine curve so that the best ultimate operating economy may be realized. By integrating with a planimeter both the station load curve and the corresponding engine curve, the average 24 hour load on the engine equipment may be readily found and the consequent water and coal consumption of the station may be checked.

An example of the effect of load factor on the economy of a power station is afforded by Fig. 5, showing the cost of power in a 7 500 kw light and power plant using steam turbines. Starting with a rather low load factor, the operating cost was reduced from 0.5c to 0.235c per kw-hr., or 42.5 per cent with an increase of only 13 per cent load factor. Fig. 6 similarly shows the average results from a 750 hp producer gas power plant, subject to a variable industrial load during the various seasons. The curve is practically an hyperbola, as it should be, and, within the working range of the plant, it shows an increase of from 1.9 to 3 lbs. of coal per kw-hr., or 27.5 per cent with a decrease of 60 per cent in load factor. At normal working the plant used less than 2 lbs. of coal per kw-hr.

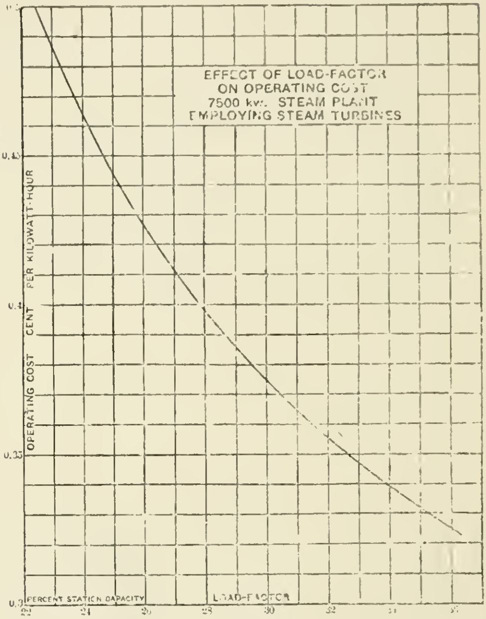

FIG. 5

When speaking of total costs of power, fixed or capital costs must be taken into consideration as well as operating costs, and as a matter of fact the effect of load factor is about as pronounced in one case as in the other. With a high load factor, 50 to 70 per cent, such as occurs in a large railway plant, a small change has comparatively small effect owing to the flatness of the curve, but in a lighting plant where the load factor ranges from 15 to 25 per cent, the values change with great rapidity.

An excellent method of obtaining a clear idea of the effect of load factor is by means of a diagram like Fig. 7, similar to that proposed by Dr. Mertz. In this diagram the capital costs are plotted above and the operating costs below the horizontal axis, the total ordinate giving the total cost of power. The combined effect of the two curves is very striking, emphasizing the necessity of increasing the average all day load upon a power station by every legitimate means; also the necessity of restraining as much as possible the capital cost of a power station necessarily operating on a low load factor.

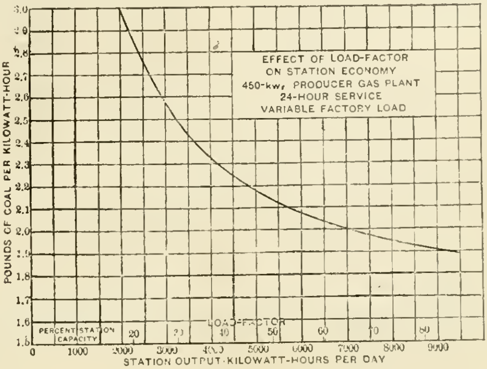

FIG. 6

In compiling these operating cost data nothing facilitates the work more than accurate and complete station records, in fact it is almost impossible to make intelligent deductions without them. American power plant managers are particularly prone to laxity in the matter of keeping records, especially in the smaller plants, which condition is directly responsible for the small amount of accurate data available on power plant operation. A little effort spent in keeping accurate records will invariably bring large returns in locating the causes of abnormal results and indicating a solution to many other complex problems of power plant operations.

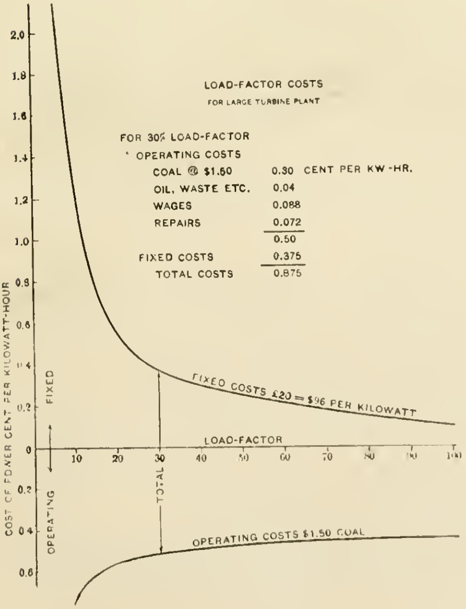

FIG. 7

LOCOMOTIVES VS. MOTOR CARS*

CLEMENT F. STREET

Commercial Engineer, Westinghouse Electric & Manufacturing Company

IN connection with the question of substituting electricity for steam in the operation of suburban service one of the problems which must be solved is whether electric locomotives or motor cars shall be used. Local conditions must necessarily have an important bearing on the problem, but as a general proposition the following will apply:—

1—With an approximate fixed weight for the majority of trains, locomotives have advantages.

2—With a variation in the weight of trains, motor cars have advantages, and these advantages increase about in proportion with this variation.

Some of the advantages of electric locomotives in this class of service are as follows:

(a) A smaller number of parts to be inspected. In the electric locomotive the motors are of larger capacity than on motor cars and are, therefore, less in number. Obviously, a small number of motors and control equipments can be more readily cared for than a large number and, therefore, the amount of time required for inspecting the electric apparatus on a train equipped with electric locomotives will necessarily be less than that required for inspecting one equipped with motor cars.

(b) The parts to be inspected are easier to get at. In electric locomotives the unit switch group, air pumps and all auxiliary apparatus are located in the cab of the locomotive where they are accessible and can readily be inspected without the use of a pit. This accessibility also facilitates the making of repairs.

(c) The cars used in the service can be changed at any time. If it is desirable to add cars to the equipment in this service which have been used with steam locomotives, this can be done without regard to whether they are fitted with electric wiring.

If there must be a variation in the number of cars in the trains, the locomotive is at a decided disadvantage. Just wherein this lies is clearly shown in Figs. 1, 2, 3 and 4. These diagrams are based on operating trains consisting of from 3 to 13 cars inclusive, in which the locomotivestives weigh 85 tons; motor cars 52 tons, and trailers 37 tons. The operating of trains of from 3 to 6 cars inclusive is contemplated with one locomotive; and trains of from 7 to 13 cars inclusive with two locomotives.

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*From a paper read before the New England Railroad Club, May, 1906.

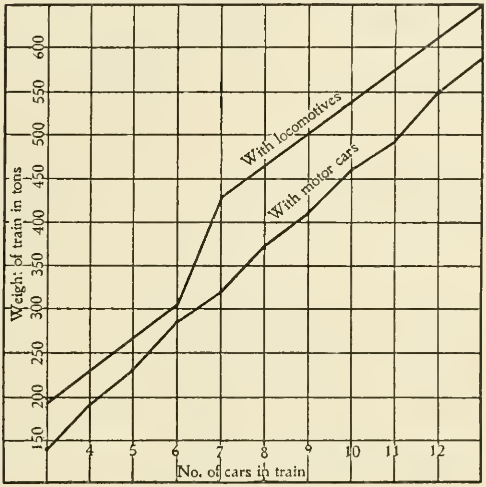

FIG. 1

From Fig. 1 it will be seen that the weight of all trains with motor cars is less than that of trains with locomotives, which means that with locomotives unnecessary dead weight must be hauled. The greatest variation in this weight in in trains of seven cars, where, with motor cars, the weight is about 320 tons; while with locomotives it is about 440 tons. It will be noted that with trains of six cars there is very little difference in the weight of the equipment; and if trains of this weight could be maintained, the advantage of motor cars in relation to dead weight would not be of consequence.

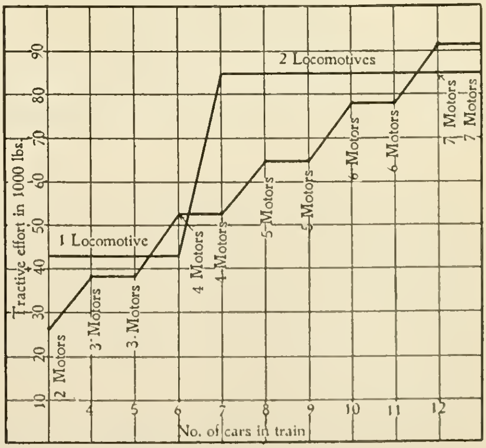

FIG. 2—ONE LOCOMOTIVE HAS 42 500 LBS. TRACTIVE EFFORT. ONE MOTOR CAR HAS 13 000 LBS. TRACTIVE EFFORT

Fig. 2 shows the fort of trains operated fort oftrains operated under the same conditions. In this diagram it is assumed that the motor cars weigh 52 tons, that the motors are both mounted on one truck and that one-half of each motor car is available for tractive effort. In making this diagram 25 per cent of this weight and 25 per cent of the weight of the locomotives are assumed as being the tractive effort. From this diagram it will be noted that the tractive effort with motor cars increases almost in proportion to the number of cars in the trains, while with the locomotive equipment there is a wide variation.

Fig. 3 shows the comparative horse power of the two classes of equipment in relation to the weight of trains in tons. This diagram is based on the assumption that each locomotive is equipped with 4 250-hp motors, and each motor car with 2 200-hp motors.

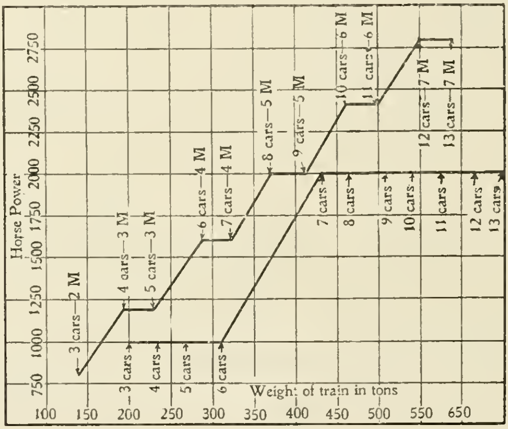

FIG. 3

From this it will be seen that the horse power with motor cars increases almost in proportion to the weight of the train, while with the locomotive equipment there is a wide variation. The locomotive is at the greatest disadvantage in handling trains of 6, 12 and 13 cars. With trains of 8 and 9 cars the horse power is the same with both systems, but the motor cars have an advantage of nearly 100 tons in dead weight.

The equipment as assumed in this diagram is a normal one and one which is being employed in actual service, excepting that the weight of the motor cars in relation to that of the trailers is greater than required. This extreme weight is assumed in order to give the locomotive every possible opportunity for making a good showing.

It might be argued that the power of the motor car equipment has been assumed as being too great in comparison with that of the locomotive, and, therefore, Fig. 4 is presented as showing a comparison which is possibly more fair. In this the equipment of each motor car is taken at 2 150-hp motors. From this diagram it will be seen that there is very little difference between the two systems, from the power standpoint, with trains of 4, 5, 12 and 13 cars, but with any other size of train the motor car is the best.

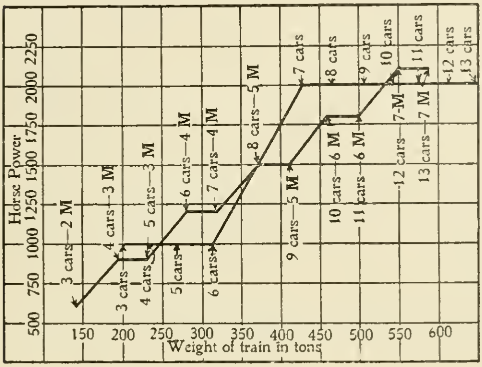

FIG. 4

These diagrams all indicate that unless it is possible to operate a service with trains having an approximate fixed number of cars and weight, the motor car equipment has an advantage from every standpoint; while if it is possible to operate service with trains having an approximate fixed number of cars and weight, a locomotive can be designed which will meet the conditions almost, if not fully, as well as a motor car equipment, and have the advantage of being more easily inspected and cared for.

In this connection, however, the motor equipment has an advantage in the fact that in the case of a failure which necessitates it being taken out of service, the equipment is crippled to the extent of only one car; while a failure of a locomotive means the putting out of service of the entire train. The motor car also has the advantage in that in case of a failure of a motor or any part of a truck, this truck can be removed and a new one substituted in less time than with a locomotive. If rapid acceleration or variation in the rate of acceleration of different trains is desired, the motor car has great advantages. A train consisting of ten motor cars of the characteristics given in Fig. 2 would have 4 000 horse power, which would give a rate of acceleration far beyond any requirements at present known. A wide variation in the accelerating power of different trains having the same number of cars can be obtained by varying the proportion of motor cars to trailers.

The foregoing relates entirely to the operation of suburban traffic. If the entire traffic over a portion of a given line must be operated by electric equipment, the problem is very different, and it practically compels the use of electric locomotives for the operation of at least a portion of the trains as it is not practical to equip sleepers, dining cars and chair cars with motors which will be used on only a portion of a run. With this class of traffic the electric locomotive has the great advantage in that any locomotive can be attached to any train, and if possible, the suburban traffic should be handled by locomotives, as the larger the locomotive equipment, the greater will be the flexibility of the service. It is also an advantage to have all the equipment as near alike as possible, and under some conditions the introduction of motor cars for the handling of a suburban service mixed with locomotives handling through trains would be a disadvantage. With heavy suburban traffic such as exists about New York or Boston, the greater proportion can be handled in trains of practically fixed weight and number of cars, and as has been demonstrated, where it is possible to hold to these conditions, a motor car equipment has very few advantages over electric locomotives.

COMPARATIVE COST OF MAINTAINING STEAM LOCOMOTIVES AND ELECTRIC EQUIPMENT

One of the problems which must receive due consideration in connection with a change from steam locomotives to electric equipment is that of the cost of maintenance, and this problem has been the subject of more or less discussion in clubs of this nature. At a recent meeting of the New York Railroad Club a comparison was made between the equipment at terminals necessary for handling electric and steam locomotive equipment, in which the impression was given that the former required a greater amount than the latter. An investigation of the subject will hardly bear this out as one of the heaviest items of expense incident to the maintenance of steam railroads during the past few yeears has been the extension to and construction of repair shops, and some of our large steam railroads now have several million dollars invested in shops for making repairs to locomotives alone. An investigation of the electric lines will show that no such investment is necessary for the maintenance of this equipment. For instance, at the terminal of the underground system of the Interboro railway in New York we find a repair shop of very small dimensions, containing a very few machine tools, all of light capacity, and giving employment to probably forty or fifty men. In this little shop all of the repairs are made to an equipment of 430 motor cars each equipped with two 200-hp motors, or a total equipment representing 172 000 hp in 860 motors. This would be equivalent to 215 steam locomotives of 800 hp each. It wil be found that a steam railroad having in the neighborhood of 200 locomotives to keep in repair has shops covering many times the area of those of the Interboro and containing equipment of tools and machinery much more extensive and giving employment to five or six times as many men; and in addition, several round-houses any one of which represents a greater investment than the entire Interboro shops. This, however, does not begin to represent the total difference between the cost of maintaining steam locomotives and electric equipment.

The average terminal charge for cinder pits, turntables, inspection, etc., is about $1.50 per locomotive which enters the terminal, while the corresponding cost per motor car is only from 20 to 25 cents. Assuming that three motor cars are equivalent to one locomotive, this gives a terminal charge of 65 cents for motor car equipment against $1.50 for steam locomotives.

The average cost of maintaining steam locomotives has for some years past, owing to the great increase in the weight of these machines, increased to figures which are somewhat startling. On one of the largest railways of this country the cost per locomotive per year for 1904 was $3 772.00; for 1905, $4 165.00. On another road the cost for 1905 was $3 473.00 per locomotive. On another, $3 565.00. These, however, are exceptionally high figures, as on some roads the cost has been as low as $1 200.00 to $1 500.00. On thirteen of the largest railways the average cost of 7 228 locomotives for 1904 was $2 212.00. The average cost per year for maintaining an aggregate of 7 684 motor cars, making an aggregate of 157-059 486 car miles, was only $107.00 per motor car per year. The average for maintaining the steam plant, electric plant and cars, including electric equipment, on these roads, was only $255.00 per car per year, or about one-eighth of the cost of maintenance per locomotive per year on the thirteen steam roads referred to.

It is only reasonable to suppose that the cost of maintaining electric motors on roads such as are now being operated by steam locomotives will be much less than the cost of maintaining motor cars on street railways, as the amount of dust and dirt to which they will be subjected will be very much less.

A comparison of the number of parts subjected to constant wear on steam locomotives and the electric equipment shows that it would be only reasonable to suppose that the cost of maintenance will be very much less on the latter. The parts of steam locomotives subject to constant wear during service are as follows:—

1 Cylinders
2 Guides
3 Cross Heads
4 Crank Pins
5 Links and Blocks
6 Valves
7 Valve Rods
8 Rocker Arms
9 Rocker Shaft
10 Pistons
11 Piston Rods
12 Piston Rod Packing
13 Valve Rod Packing
14 Reverse Lever
15 Throttle
16 Throttle Packing
17 Truck Axle Bearing

The parts of electric equipment subject to constant wear are motor bearings, brushes, commutators and trolley. With motor cars gears should be added to this list, and with electric locomotives having forced ventilation the ventilating fan and fan-motor should be added. The wear of brushes is a small item as the tests made with the New Haven locomotive show that one set will run 12 000 or 15 000 miles, which will represent from two to three months' service.

It might be argued that controller fingers and unit switch fingers should be added to this list, but the wear on these parts is small. Controller fingers with multiple switch control are subjected to only fourteen volts and seldom give out. The multiple unit switch fingers have been subjected to most severe tests and several of them have broken the current to which they are subjected in service one hundred thousand times without being worn out.

Portions of the electric equipment are of course liable to be burned out owing to short-circuit or abuse, but the liability of such failure is not greater, if as great, as that of burning a crown sheet or flues in a steam locomotive boiler owing to low water, and the results are not nearly so disastrous as they are never accompanied by a loss of life and seldom by the laying down of the train. If a flue blows out or the crown sheet goes down in a locomotive, it must abandon its train and be hauled home dead, if it has not been derailed, while if a motor is burned out, this motor can be cut out and the car or locomotive can take its train home without difficulty.

"IDLE CURRENTS" *

JOHN S. PECK

Chief Electricul Engineer, British Westinghouse Electric & Manufacturing Company

MR. FIELD has dealt in his paper with the question of idle currents in armature conductors. Difficulties of the same nature, however, have been encountered in the design and operation of transformers. In 1892 the Westinghouse Company designed a small transformer which was intended to have an extremely high efficiency. In order to keep down the copper losses, the low-tension winding was composed of large rectangular copper strap. When the transformer was put on test, the designers were greatly surprised to find that the low-tension winding reached an excessively high temperature. After some consideration it was decided that the excess heating was due to eddy-current or idle-current loss in the rectangular strap, the currents being set up by the leakage magnetic field through the windings. It was realized that this was a matter little understood, but which would have great weight in the design of large transformers. A series of investigations were therefore carried out, using wires and straps of various dimensions placed in different ways in magnetic fields of different densities and frequencies. From these tests, supplemented by theoretical considerations, curves were plotted showing what idle-current losses might be expected in copper conductors under different conditions. These curves enabled the transformer designer to choose such conductors as to avoid excessive losses due to local currents set up within the conductor. It was found, however, that parallel conductors—even though insulated throughout their entire length—were subject to much the same idle-current losses as solid conductors unless properly transposed. Another difficulty which has been frequently encountered is due to the attempt to operate in parallel coils which are not located in symmetrical magnetic positions, so that on account of the difference in the leakage magnet-

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*A discussion by Mr. Peck of a paper entitled "Idle Currents," by Mr. M. B. Field, Manchester Local Section, Institution of Electrical Engineers, from the Journal of the Institution, Vol. 37, No. 179, issued August, 1906. The paper discusses power factor, wave shape, cross-currents, internal idle currents and armature idle currents, treating the matter from a descriptive and theoretical standpoint and citing instances in operating experience which are pertinent to the subject.

ic field cutting the two coils, unequal voltages are induced. Once the reason for this inequality is understood, no trouble should be encountered in designing a transformer to avoid this difficulty, but until it was understood some very puzzling results were obtained. I believe that no trouble occurred caused by the displacement in the end windings of generators and transformers until units of very large size were installed. A certain amount of trouble was encountered with the Niagara generators' winding, caused by displacement of the coils in the event of one machine being thrown in parallel with other machines when out of phase. Methods were devised for bracing this winding, and great care is given to this bracing in all machines of large capacity. In the Chelsea generators referred to by the author, the coils were braced in a manner which it was thought was amply sufficient. It was found, however, that when one machine was thrown in parallel out of phase with other machines, the forces were so enormous that the supporting blocks were crushed and torn loose from their supports. Shortly after the first Niagara machines were installed, a short-circuit occurred on the secondary circuit of a 200 kw transformer. An examination of the transformer showed that when the short occurred the out side end coils which project beyond the iron core had been bent over at right angles and flattened against the end frames which held the laminations together. These coils were wound with large rectangular wire, several wires in parallel, so that an enormous force must have been required to bend the coils into the position in which they were found. After this accident steps were taken to brace the coils of large transformers in order to prevent their being thrown out in case of sudden short-circuits. In very large transformers having extremely close regulation it is necessary to take the greatest care in bracing the coils in every direction, as the currents which flow through the coils of such a transformer in the event of a short-circuit may be twenty to forty times the normal, thus producing forces between the coils four hundred to sixteen hundred times the normal force.

THE TREATING OF TRANSFORMER OIL

S. M. KINTNER

THE successful operation of the higher voltage transformers depends very largely on the condition of their insulation. As all transformers of this class are oil insulated and rely to a considerable extent upon the oil for their insulation, it is of the utmost importance that the oil should be in prime condition. The condition of the oil is of more and more importance as the voltages are increased.

It is generally known that the presence of water in oil is detrimental to its insulating qualities, yet it is hardly appreciated how slight an amount of water or moisture is required to very materially reduce the dielectric strength of oil. Mr. C. E. Skinner, in an article in the May, 1904, issue of the JOURNAL, called attention to the extreme sensitiveness of oil and gave a curve showing dielectric strength for various percentages of moisture. It will be noted on reference to this curve that 0.04 of one per cent moisture, or four parts in 10 000, is sufficient to reduce the dielectric strength of the oil one-half. The experience of the writer indicates that oil is even more sensitive to change than stated by Mr. Skinner. There have been a number of instances where careful chemical analysis failed to show the presence of moisture, when an electrical test indicated its presence, this last fact being established by re-testing the oil after the removal of the moisture.

It is hardly necessary to dwell at any length upon the many ways in which oil can accumulate water and moisture, as these are generally known. The question, however, that frequently confronts the operating engineer is how to remove the moisture from his transformer oil.

It is a simple matter to tell whether the oil has moisture provided there is very much water present, as it will readily settle out in the bottom of a sample drawn from the lowest point of the transformer. Another test that is more sensitive, and is in fact amply sensitive for a large majority of cases, is to thrust a red hot nail or rod into a sample of oil under test. If the oil "crackles" like frying grease, water is present. In the absence of moisture there will be no crackling sound when the rod is thrust into the coil. In the electrical test of dielectric strength average dry oil should not be weaker than 30 000 volts as the mean of ten tests for a 0.15 inch gap between one-half inch spheres. The oil should not break below 25 000 volts in any of the ten tests.

There are six ways of effecting the separation of oil and water, —(1) mechanical separation, (2) capillarity, (3) electro-static force, (4) heating, (5) vacuum and heating, and (6) dehydrating.

MECHANICAL SEPARATION

When the oil contains considerable water or moisture, its greater density will cause a separation between the two materials, the water settling to the bottom. After this separation, the excess water can be readily drawn off. The same separation can be effected by passing the material through a centrifugal machine. The water in this instance will settle to the outside and can be drawn off. As the amount of drying that can be effected in this way is not sufficient for the higher voltage work this separation needs to be followed by some other more complete method of drying.

CAPILLARITY

During the development of an oil-treating outfit, the fact was noted that certain materials had the property of allowing the water to pass through readily but still interfering with the passage of oil, this action being due, it is believed, to the difference in capillary attraction of the two materials. This fact has been made use of in a form of a separator which allows the passage of water and still retains the oil, this separator being in the form of a disc and placed so that all water and oil passing to the treating outfit passes over the disc. The disc allows the separation of the excess water and consequently relieves the treating outfit of a certain amount of work. The separation that is effected by this method is, however, of the same order as that mentioned under the heading of "Mechanical Separation," and the oil needs further treatment before it is sufficiently dry for good electrical service.

ELECTRO-STATIC FORCE

An intense electro-static field can be so arranged that it will tend to hold the water, and impurities of higher specific inductive capacity than the oil, in its denser field. This effects a certain separation, permitting the dry oil of lighter specific inductive capacity to pass to the weaker side of the field. By drawing off the oil from these several points, it is possible by repeating the process several times to effect a drying of the material. Tests that have been made on this method, while indicating the possibility of its being used, have not shown it to be entirely satisfactory. As a rule, it will be found quite difficult to operate such an arrangement, and it is on the whole not to be recommended.

HEATING

Moisture can be removed from oil by direct application of heat. This can be brought about in several ways, one of the most common of which is to immerse in the oil grid resistances which are heated electrically. The oil as a whole has its temperature raised slightly above the boiling point of water and it is maintained at this temperature until all the moisture is boiled out. The grid resistances should be placed at the lowest possible point in the oil, as otherwise all oil below these resistances will remain cold and there will be an accumulation of water at this point, with the result that if all of the oil is drawn off at the end of the drying, this moisture will be mixed in with the oil that has been dried above the grids. It is much better, if possible, to so arrange the drying tank that the heat is applied below the tank. In this manner, all of the oil that is being dried is subjected to the heat. It is necessary to maintain a temperature of 105 to 110 degrees C. and this will have to be maintained until tests show that the oil has been entirely freed from moisture. As a rule, in drying large quantities of oil, this will require from ten days to two weeks heating. The continued heating of the oil at this temperature will prove very detrimental to the oil. It will tend to break it up, separating the lighter hydro-carbons and causing certain formations in the oil due to this separation. Oil that has once been overheated in this manner is apt to continue to develop this formation when put in service and operated at lower temperatures. The oil will be very greatly changed in color, being very much darkened. On account of the change in the oil, this method is not looked upon with much favor, and should be used only in such cases where other apparatus for drying the oil is not available.

Another method of applying the heat that is sometimes employed is that of blowing hot air through the oil. In doing this it is necessary to be sure that all moisture is removed from the air that is being blown in, as otherwise the hot air will carry in moisture and condense it in the oil, thus adding to the amount of moisture in the oil rather than taking it out. This method is open, of course, to the same objection as that raised to the above, that of causing decomposition of the oil. It is believed to be somewhat worse than direct heating, as the great amount of air blown in will cause a certain amount of action which is apparently a form of oxidation, and will aggravate the decomposition of the oil and the settling out of the lighter hydro-carbons.

VACUUM AND HEATING

It has been found possible to dry oil by the use of a vacuum tank, heat being applied to the oil at the same time. The use of a vacuum lowers the boiling point of the water and consequently makes it possible to eliminate the moisture without reaching a temperature that is detrimental to the oil. This method, where available, should prove satisfactory, and it is possible to secure an oil that is perfectly dry by this treatment. As a rule, it will require considerable time to thoroughly remove the moisture, and for this reason the method is not as convenient as the one described below.

DEHYDRATING

Moisture can be removed from oil very rapidly and very cheaply by the employment of suitable agents for absorbing the moisture. The engineers of Westinghouse Company have developed a treating outfit which employs this principle, in conjunction with method (2) described above. This outfit circulates the oil to be dried through a treating tank in which is placed a dehydrating material. The oil after passing through this dehydrating chamber is filtered and thus all foreign materials that are in the oil, as well as any of the dehydrating material that may have followed through are removed. It has been found possible with an outfit of this kind to dry a thousand gallons of oil in a day, and to have this oil as dry as required for the highest voltage service. Lime is the material employed in the dehydrating tank. This material has been selected after testing a number of dehydrating agents, as it is usually available and introduces no possibility of injuring any part of the transformer if any of it gets through the filter with the oil. It has the additional advantage of tending to neutralize any acids existing in the oil. A number of other satisfactory dehydrating agents have been used and in some instances where special precautions are observed it may be found more advantageous to employ some of these than the lime. Dry sand has generally been used for the filtering material, although in some instances it has been found advantageous to mix in certain proportions of bone-black and Fuller's earth, these last two having the property of tending to clear the color of the oil. As a rule, dry sand will be found sufficient.

It is the writer's opinion that the last method mentioned will be found much superior in general practice to any of those mentioned above. The outfit that has been developed is sufficiently portable to permit of its being readily shipped from one station to another, and it is a compact unit in itself, being provided with a motor and pump, together with the necessary filtering and treating tanks, and accessories. This outfit when placed in service, and intelligently operated has proven entirely satisfactory. The oil should be tested from time to time to see that the dehydrating materials have not depreciated in strength. When the oil indicates this fact, it is necessary to re-charge the apparatus. No statement can be made as to how much oil can be treated with one charge, as this is dependent upon the amount of moisture held in suspension in the oil, which will vary with different oils and temperatures. It is quite probable that the companies operating the extremely high voltage transmission systems will find it necessary to treat the oil used in the transformers, switches, etc., periodically, so as to insure its being in the best possible condition. For such treatment as this, an outfit of the kind just described is very effective.

THE KELVIN SECTOR AMMETER AND VOLTMETER

M. C. RYPINSKI

SMALL switchboards for stations having capacities of 50 kw and under are subject in their layout to economy considerations which do not enter into the design of larger switchboards. Instruments are a considerable factor in the expense of switchboard apparatus, and the smaller the installation the greater this factor becomes. A considerable demand has, therefore, arisen for a switchboard meter which would compare favorably in accuracy with the ordinary high grade meter and which could be marketed at a lower price. As switchboards for small stations are of the simplest character, this demand has been limited to alternating and direct-current ammeters and voltmeters. The Kelvin sector-pattern meter as manufactured by the Westinghouse Company, is an interesting example of what is being done to meet this requirement.

The instruments, built after the inventions of Lord Kelvin, are widely known for the high accuracy they develop and for their rugged simplicity. It is interesting to note that he never employs the jewel and pivot mounting, but uses arrangements such as the knife-edge bearing, the filament suspension or the ligament suspension; examples of which appear respectively in the sector meter, his portable electrometers, and his permanent magnet switchboard instruments.

The action of the sector meter depends upon the pull exerted on an iron core suspended within a solenoid acting in opposition to the pull of gravity on counterbalancing weights. The novelty of the device lies in the use of a long solenoid giving an intense and uniform field in combination with a saturated core and an ingenious control mechanism. The core is made of a special grade of iron remarkably low in magnetic retentivity.

The advantages which this meter possesses over other meters of its class are:—

1—A scale with approximately equal divisions.

2—It is unaffected by external fields.

3—Freedom from frictional error.

4—Capability of standing any amount of rough usage.

5—It admits of adjustment or repairs by the ordinary station attendant.

6—The residual error on direct-current is very small. It is subject on alternating-current to a wave form and frequency error, but on calibrating for the frequency and wave form on which it is to operate, correct indications are obtained.

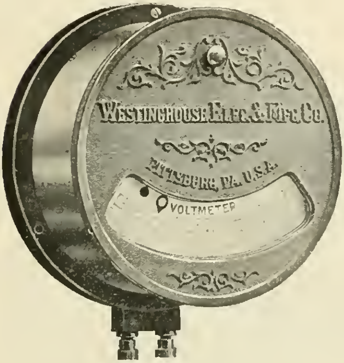

FIG. 1

The uniform scale is obtained by having the actuating and controlling forces vary according to same law, as is explained in the following description. A uniform scale is a very desirable feature for a meter to possess, as it allows accurate readings to be made at any part of the scale instead of limiting them, as in the contracted scale type to fifty or seventy-five per cent of the scale capacity. The intense uniform field produced by the solenoid is so much stronger than any probable external magnetic force that fredom from external influence results. The use of a knife-edge bearing and the general simplicity of the device give it its ruggedness, ease of manipulation, and freedom from frictional error. The low residual error is obtained by the use of the special grade iron previously mentioned.

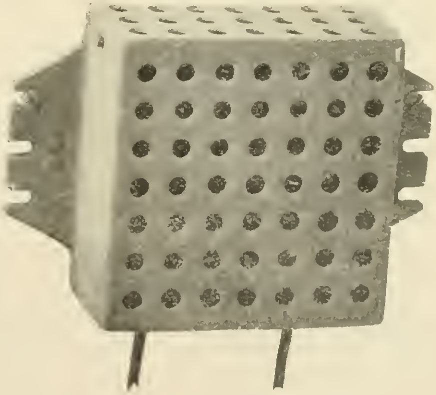

FIG. 2

A voltmeter of 150 volts capacity is shown in Fig. 1 and the external resistance for the meter is shown in Fig. 2. Fig. 3 shows the meter with its cover and dial removed. An enlarged view of the movement mounting is shown in Fig 4. These figures illustrate the appearance of the ammeter as well as the voltmeter, the only difference being that the fine wire coil of the voltmeter is replaced in the ammeter with one of larger wire and fewer turns, and the series resistance is omitted. The meters are designed so that the full-scale torque is the same for both the ammeters and the volt-meters for all capacities, thus allowing the same moving system to be used throughout. This is effected by winding the coils in inverse proportion to their full-scale current capacity, i. e., if the current capacity is to be doubled the number of turns would be halved.

The alternating and direct-current meters differ only in their calibration and the scale marking, the general design being so laid out as to avoid eddy currents in the coil mounting, which if present would heat up the meter and tend to introduce errors in the readings. In order to prevent confusing vibrations, the moving core is submerged in oil.

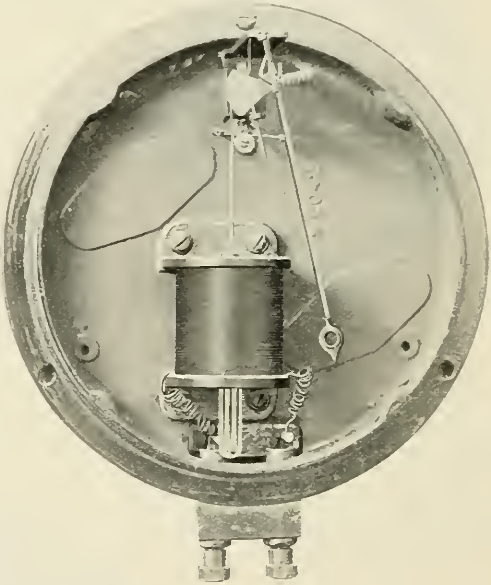
FIG. 3

The ammeters are self-contained up to 2 400 volts. For alternating-current ammeters above 500 amperes capacity, or on circuits exceeding 2 400 volts, five ampere meters with series transformers are used. Series resistance boxes are always used with the voltmeters, the voltage across the meter being about one-fourth of the total voltage. If the resistance is omitted and the total voltage applied to the meter alone, the extra heat generated by the increased current will not be dissipated fast enough to prevent the coil from burning out. On circuits of 750 volts or less series resistances are used to reduce the voltage to that required by the meter, but above 750 volts, alternating current, 150 volt meters with potential transformers are employed.

In Fig. 3 the fine wire coil of the voltmeter may be seen supporting a glass tube containing the damping oil. Within the tube is suspended the iron core. In Fig. 4, *F* is a supporting bracket attached to the instrument base, into which are fastened phosphor hooks, *K*, *K*, filed to knife-edges at their bearing-points. A steel beam *B,* drilled and countersunk for bearings, rests on the hooks *K, K,* this combination making a simple and efficient bearing, free from friction and readily removable. A pulley sector *S* is attached to *B.* Fastened to the pulley at its upper end and to a small wire hook at its lower end is a silk thread *T* on which the core *R* is hung. A pointer *P,* zero adjustment weights *E* and scale adjustment weights *D,* all rigidly attached to *B,* complete the moving system.

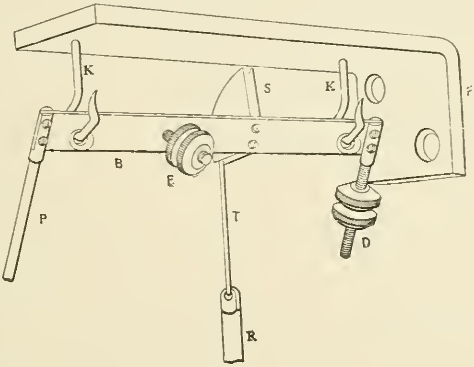

FIG. 4

Looking at the system from a mechanical point of view, it will be seen to comprise a lever arrangement in which a variable straight line pull of constant radius is opposed to a constant pull of variable leverage. The variable pull is that due to the action of the current on the core, for which pull sector *S* provides a constant leverage. The action of gravity on the controlling weights provides the constant opposed pull, the movement of the weights, through a circular arc, away from the vertical line of support, giving to the opposite pull a variable leverage.

With no current flowing (pointer reading zero), a condition of equilibrium exists, in which the center of gravity of all that part of the moving system except the core is displaced to the right a sufficient amount to counterbalance the core. When current is applied the coil magnetises and attracts the core, thus exerting a pull on the system and causing the pointer to move to a position where the displacement is sufficient to re-establish equilibrium. This latter condition may be expressed by the equation,

$$pr=(W\text{-}w\ r^1 \sin a.$$

where p=the pull due to current, r=the radius of sector, *S,*

$(W'-w)$=the weight of the system less that of the core, r^1=the radius of $(W'-w)$ assumed concentrated at the center of gravity and a=the angular deflection of $(W'-w)$ due to the current; $r^1 \sin a$ being the horizontal displacement or leverage of $(W'-w)$. pr the value of the actuating torque and $(W'-w)\ r^1 \sin a$ the opposed controlling torque. This equation shows that the controlling torque varies according to a sine function of the angular deflection and that the actuating torque must also vary according to a similar sine function of the current if a uniform scale system is to exist. The value of the actuating torque depends upon the variable p and this in turn depends, as a rule, upon three variables:—

1—The current, in its effect upon the magnetising force of the coil.

2—The current, in its effect upon the induction of the iron core.

3—The position of the core with reference to the coil.

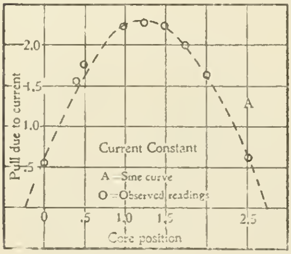

FIG. 5

It is an interesting fact that with a coil and core arranged as in this meter, the third variable follows a sine law. This is well illustrated by Fig. 5, in which the result of a test has been plotted giving the relation between p, the pull due to current, and the relative position of the core with respect to the coil; the current being maintained constant throughout the test. By saturating the core its induction becomes constant, thus eliminating the second variable, and with it the second power of the current which would otherwise give a contracted scale following the law of squares. The saturation of the core is illustrated by Fig. 6 in which the relation between p and the current is plotted, the position of the core being maintained constant. The approximation of the readings to a straight line law rather than to a law of squares shows that the first variable follows a straight line law in its effect upon the pull, p. By combining the effect of the first and third variables, the property of varying as a sine function is given to the pull, p, and a uniform scale results.

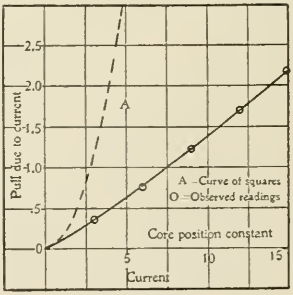

FIG. 6

DYNAMO AND MOTOR PULLEYS

T. D. LYNCH

A LARGE proportion of the dynamos and motors now being built are designed for belt drive and it necessarily follows that suitable pulleys must be provided. The making of pulleys is recognized as one of the older manufacturing industries but as such it covers pulleys for engines and countershaft work where the speeds are not excessive and where close fits and accurate balancing are not pertinent factors.

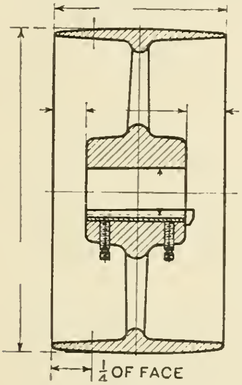

FIG. 1—STANDARD PULLEY WITH DIMENSIONS TO SHOW OFFSET

Pulleys that are for use on dynamos and motors must have accurate bores and be in perfect balance so that the rims will run true and not create vibrations when running at high speeds. Power houses are constantly being erected where similar units are placed side by side. These machines are carefully designed to give a pleasing effect to the eye, so that it becomes necessary to have the pulleys, also, conform to a common design, have a uniform thickness of section and the same general appearance. This demand has been created in recent years and it has been necessary to set a new standard of precision suitable for this service and gradually bring the pulley manufacturers up to it. It was found necessary to work out and standardize a great many details before the different manufacturers would recognize the precisions required for this service. In order that there should be a definite understanding of the requirements necessary for this class of work a set of specifications for pulleys was recently gotten out and adopted by the Westinghouse Electric & Mfg. Company.

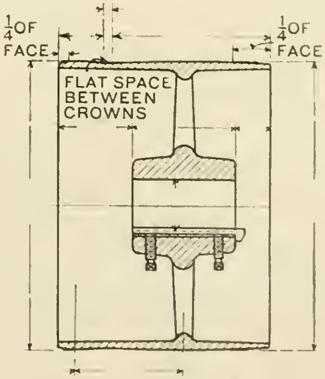

FIG. 2—DOUBLE CROWN OFFSET PULLEY

For the benefit of those who may have occasion to order pulleys for high speed service, some of the main features that have been found to be necessary to take into account in order to get satisfactory pulleys are given herewith.

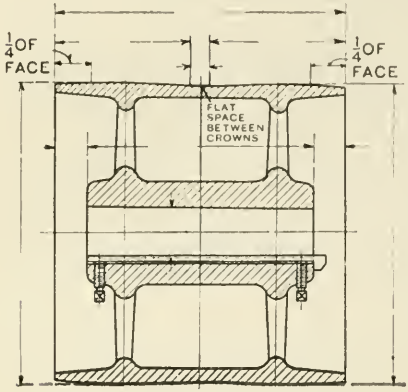

FIG. 3—DOUBLE CROWN PULLEY

DESIGN

In the main, it is best to leave the general design of standard pulleys to the pulley manufacturers, but they do not agree among themselves on a number of points that are of more or less interest to pulley users. It is therefore necessary, for the sake of uniformity, to adopt a compromise. The following seems to meet these conditions and is found to meet the general wants quite well:

Pulleys six inches in diameter or less should be made with webs instead of arms. Pulleys that have their diameter and face in accordance with those given in the following schedule should have single arms. In all other instances the practice of the manufacturer in regard to double arms should prevail.

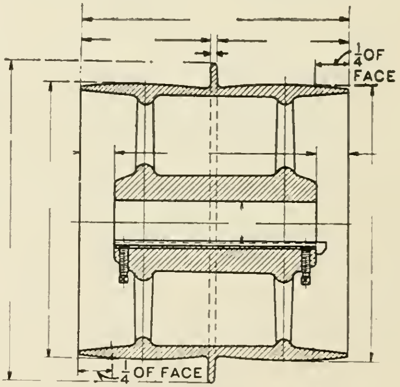

FIG. 4—DOUBLE CROWN PULLEY

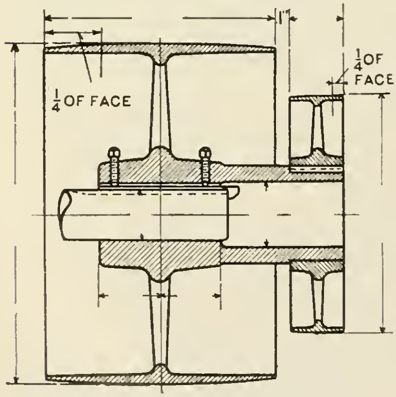

FIG. 5—DOUBLE CROWN PULLEY

9	in.	diameter	up	to	8	in.	face
10	"	"	"	"	9	"	"
11	"	"	"	"	12	"	"
12	"	"	"	"	10	"	"
13	"	"	"	"	14	"	"
14	"	"	"	"	10	"	"
15	"	"	"	"	12	"	"
16	"	"	"	"	12	"	"
17	"	"	"	"	12	"	"
18	"	"	"	"	12	"	"
19	"	"	"	"	12	"	"
20	"	"	"	"	11	"	"
21	"	"	"	"	14	"	"
23	"	"	"	"	14	"	"
25	"	"	"	"	15	"	"
26	"	"	"	"	16	"	"
27	"	"	"	"	16	"	"
30	"	"	"	"	16	"	"

DIAMETER

The diameter of a pulley should be as accurate as possible, and measured at a point one-half way between the edge of the rim and the crown. The allowable variation in diameter should not exceed plus or minus one-sixteenth inch up to 20 inches diameter and plus or minus one-eighth inch for larger sizes. A great deal of motor drive is such that the rate of speed is a very essential feature and the only way to get accurate speeds is to have pulleys with accurate diameters.

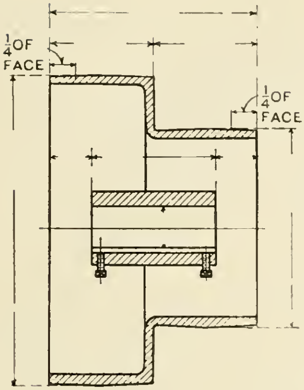

FIG. 6—TWO STEP CONE PULLEY

BORE

The question of bore probably gives greater concern than any other individual feature, since it is found necessary to keep the variation of bore diameter in dynamo and motor pulleys between exact size and 0.002 inch over size for bores up to two and one-half inches in diameter and a variation between exact size and 0.003 inch over size for bores larger than two and one-half inches in diameter. In addition to accuracy of diameter, it is also necessary that the bore should be straight and true in every way. The thickness of the rim is also quite an important feature because a heavy rim gives a proportionately heavy weight and throws almost the entire weight of the motor on a single bearing. Hence a reasonably light rim is recommended.

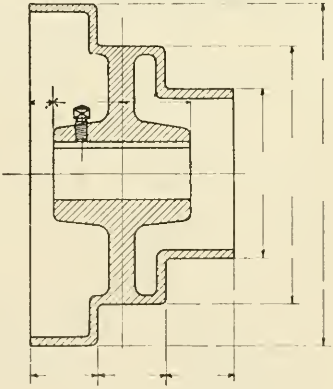

FIG. 7—THREE STEP CONE PULLEY

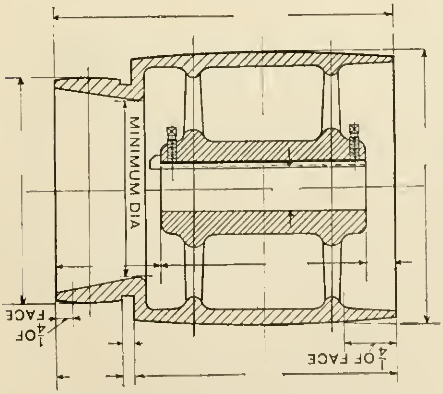

FIG. 8—DOUBLE CROWN PULLEY

HUB

The hub should be central with the pulley face, except in the case of offset pulleys. The allowable variation in the length of the hub sometimes affects the clearance of the dynamo or motor to which it is to be attached, while the diameter of the hub affects the general appearance of the pulley when in service.

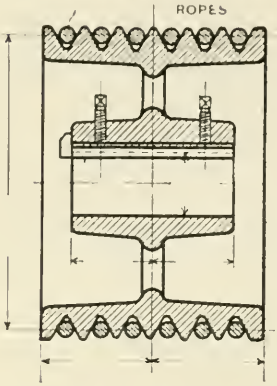

FIG. 9—ROPE SHEAVE PULLEY

Set screws form a part of the hub. They should be radial, over the center of the key and properly put in to make sure that the key will be held firmly in place.

KEYWAY

The keyway must be very exact to size so that there will be no vibration of the key in stopping, starting or reversing the pulley, since a key that is given any play will work itself loose and mash the keyway. In all cases the keyway should have square corners and be cut radial, with the sides and bottom parallel, with the bore.

BALANCING

It has been found that a pulley which has been given a careful static balance will give good service, but when not accurately balanced a vibration is set up in the motor which is very detrimental to the efficiency and life of the machine.

MARKING

The question of marking, which in itself seems to be a small matter, has been found to be one of considerable importance on account of the fact that pulleys of a given size are often made with different diameters of bore, and in carrying such pulleys in stock there is great danger of shipping the wrong pulley. Hence there is a decided advantage in having the diameter of the bore stamped on the end of the hub. This, together with the manufacturer's initials, also stamped on the end of the hub, gives an absolute identification.

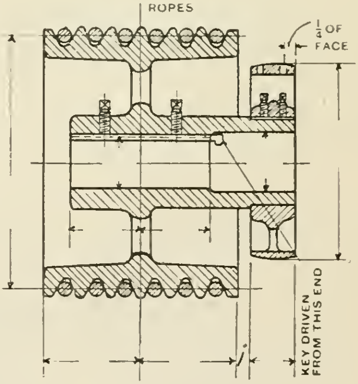

FIG. 10—DOUBLE CROWN ROPE SHEAVE PULLEY

SPECIAL PULLEYS

It often happens that a pulley of special shape is necessary or very desirable. In Figs. 1 to 10 are shown a number of special pulleys. The necessary dimensions are indicated in these figures by the dimension lines, the distances being left blank. A sketch of a standard pulley is shown in Fig. 1 in which the dimension lines are given for a pulley whose arms and hub are not central, i. e., they are to be offset from the center, the amount of offset to be shown by the dimensions filled in. In Fig. 2 is shown a double crown pulley made so that the main and exciter belts may both be run on the one pulley face. Figs. 3 and 4 show double crown pulleys for two heavy belts. A double crown pulley with a smaller pulley fitted on the hub of the larger pulley is shown in Fig 5. The dimensions and general design for two and three-step cone pulleys are shown in Figs. 6 and 7. A form of double crown pulley with two diameters is shown in Fig. 8. Two forms of sheave pulleys are shown in Figs. 9 and 10, the latter one having a small belt pulley fitted on its hub.

These forms of special pulleys are the more usual ones and will give the reader a general idea of what forms of special pulleys are commonly made. It is recommended, however, that special pulleys should not be specified except when standard central hub pulleys will not meet the service required.

ORDERING

Too great care can not be given when placing orders for pulleys to see that all the necessary data is plainly given.

The following items should be included in the order: (1) Kind of pulley—single, double or triple crown. (2) Material of which pulley is to be made. (3) Some identifying or specification number. (4) Power to be transmitted. (5) Speed. (6) Diameter of the pulley. (7) Width of the pulley faces. (8) Bore. (9) Keyway—(a) width, (b) depth. (10) Hub — (a) length, (b) amount of offset when offset pulleys are to be ordered.

By following the above outlined suggestions, it has been found that pulleys can be had for dynamo and motor service that will give the very best satisfaction.

EXPERIENCE ON THE ROAD

K. E. SOMMER

A POLARITY INDICATOR

A SHORT time ago a report was received stating that two 75 kw, 125 volt generators would not operate in parallel. On arriving at the plant and making an examination the connections from the generators to the switchboard were found to be correct. The generators were then tested separately with the available loads, and their behavior as to commutation, compounding, etc., was all right. When thrown in parallel the circuit breakers opened instantly. Opposite polarity alone could have caused such sudden results, inasmuch as both generators were of the same voltage when paralleled. Apparently the switchboard voltmeter, although marked "Direct Current," was not an indicator of polarity. The writer had no portable Weston instrument at hand. Recourse was therefore had to a tumbler of acidulated water in series with an incandescent lamp as a preventive resistance. This device was connected successively across the terminals of each generator. In one case bubbles appeared in the water at one terminal, in the other case at the other terminal, indicating that the generators had been paralleled when of opposite polarity. One machine was "re-flashed" from the other by passing an exciting current in the proper direction through its field winding, and no further trouble was experienced with parallel operation.

ROTARY CONVERTER TROUBLE

A 200 kw, 60 cycle, 600 volt rotary converter was reported operating unsatisfactorily. It was suggested that the lowering transformers might be connected improperly, or that the insulation of the converter was imperfect, in fact a number of causes for the unsatisfactory operation of the machine were advanced. Investigation showed the transformer connections were all right, and the insulation of the machine not defective. The substation operators reported that at times the rotary operated very satisfactorily, and at other times very unsatisfactorily. The writer decided to observe operations closely for a few days. Readings of loads were taken for three or four days and the behavior of the machine and time of readings noted. The power for this converter came from a large lighting and power station. Through the kindness of the superintendent of the company, access was had to the switchboard record sheets. On comparing the writer's observations and the switchboard attendant's sheets, it was noted that the operation of the converter was always bad when two particular generators in the power house were supplying power to the bus-bars to which the converter was connected. When the other generators were supplying the power, the operation of the converter was good, and particularly with one 3 000 kw fly-wheel type generator supplying power, the behavior of the converter was very good indeed, loads up to 100 per cent. momentary overload being satisfactorily carried. It was found that the machines that supplied power during the periods of unsatisfactory operation of the converter did not have copper dampers. As the rotary itself was obviously not defective, an agreement was entered into between the railway company and the power company, by which the latter was to furnish power only from the generators which gave satisfactory service.

ALTERNATOR TROUBLE

A telegram in this case read: "Go at once to ———ville, lighting company cannot get voltage from generators." At the plant were two single-phase belted generators, a 90 kw machine of modern type, and a 150 kw of an obsolete type, purchased from a second-hand dealer. The 90 kw generator was found running at 2 100 volts as indicated by an instrument having a 2 500 volt scale. By adjusting the compensator brushes, a reading of 2 300 volts was obtained, or 200 volts higher than the desired operating voltage. The 150 kw generator could not be made to show more than 2 150 volts, although the speed was approximately correct and ample separate excitation was provided. A Weston portable voltmeter was attached to the secondary of the switchboard voltage transformer of the 150 kw generator. The Weston instrument indicated 2 350 volts simultaneously with the switchboard reading of 2 150 volts. The Weston voltmeter was then connected to the voltage transformer of the 90 kw generator, and this reading checked exactly with the simultaneous reading of the switchboard instrument. As the 90 kw generator had an armature with distributed winding and the 150 kw generator had a "toothed" armature, the voltmeter discrepancy was evidently due to the distorted wave form of the 150 kw machine. The Weston instruments indicate correctly the effective value of the e.m.f. irrespective of wave form; while the deflection of the switchboard instrument, which was of the type "K" style is effected by the wave form, owing to the variation in permeability of its iron parts at different indications. As a matter of fact, the type "K" instruments should be especially calibrated for use with currents of distorted wave form. It was next decided to operate the machines in parallel, but owing to the distorted wave form of the 150 kw generator, parallel operation was unsuccessful, and another generator was purchased in place of the "toothed" armature generator.

BALANCE COIL TROUBLE

In another case, undue heating of the balance coils, used in connection with a 20 kw, 250 volt, three-wire generator, was reported. The voltage and frequency was found to be correct, as were also the connections between the generator and the balance coils. The loads were not above the rated capacity, nor was there excessive unbalance. A 25 ampere alternating-current ammeter was placed in the circuit of the phase "A" balance coil, while the brushes were raised from the collector rings connected to the phase "B" coil. The magnetizing current was inappreciable, being too small for accurate reading on the ammeter. The brushes were then placed in position on the phase "B" collector rings. With both balance coils connected and zero load on the generator, the alternating-current ammeter read 12.8 amperes. The ammeter was then placed successively in each leg of the circuit to the balance coils, with approximately the same result in each case. With direct-current loads of 46 and 30 amperes per side, the alternating-current ammeter reading increased only to 14.9 amperes from the 12.8 ampere reading at zero load. Indications pointed to incorrect connections from the armature winding to the collector rings and an examination showed that the taps from the commutator to the collector rings were made from bars Nos. 1 and 13, 25 and 36, whereas the taps should have been made from bars 1, 13, 25, and 37. The error was at once remedied and the balance coils gave no further trouble.

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ELECTRIC JOURNAL

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The Induction Motor and Its Application

Notwithstanding the obvious advantages obtained by the use of constant speed induction motors in certain classes of industrial work, these advantages are not infrequently nullified by the careless selection and application of auxiliaries for use with such motors. As is pointed out by Mr. Reed in his article in this issue of the JOURNAL, the use of auto-starters will reduce the line current required under severe starting conditions and thereby relieve the supply system from any excessive demands. In many cases the power required by a single motor is small compared with the capacity of the supply system, so that the amount of starting current taken by an individual motor is immaterial. In other cases it is highly desirable to avoid as far as possible such excessive demands on the supply system. Nevertheless in laying out the motor equipment for mills in which starting conditions are severe, such as are met with in cement mills, the designing engineer should not lose sight of the vital importance of uninterrupted service. Continuity of service is all important. The stopping of a single motor may result in reducing the output of a plant fifty per cent. during the period of interruption. In many processes the machines driven by individual motors are expected to run for a week without stopping. It is evident that in these cases, even though the current required in starting the motor be severe on the supply system, some discomfort on that account may well be borne if by so doing the factor of reliability in starting be increased. Refinements in starting devices are not calculated to increase this factor of reliability, and unless this problem has been carefully considered for each individual application, the starting device becomes an additional link, which is apt to be the weakest link in the system between the power house and the machine to which the motor is applied. Cement mill machinery can usually be driven with constant speed motors. In this class of work variations in line voltage due to excessive starting currents are not seriously objectionable. The individual motors are relatively small in capacity in comparison to the power generators back of them, and as stops are infrequent, the elimination of starting devices on motors of small capacity is, in the writer's judgment, wholly justifiable on account of the increased reliability in service obtained thereby.

Whatever motor is selected for a certain class of service great care should be exercised in selecting starting devices—if they be used—in order to avoid introducing an element of weakness into the system. The constant speed squirrel cage type of induction motor is of rugged construction, capable of successfully withstanding hard usage; the machines driven are frequently of the same character. With ample power back of the system, elimination of a refinement in the form of starting devices is frequently justifiable on account of the increased assurance of continuity of service secured thereby.

On the subject of ratings I cannot help feel that there is a popular misconception of the proper method of rating induction motors. In a recent conversation with one of the most prominent steel mill engineers in this country the latter entered into a wholesale condemnation of present methods of rating induction motors because he could not run his motors at 175 per cent of normal rating continuously without burning out! Compare this notion with the accepted rating on railway motors, for instance. If a railway motor carries its rated current at normal voltage for one hour with a temperature rise of 75 degrees, C, it is accepted without question and nothing more is demanded. If an induction motor will safely carry 175 hp with adequate margin in overload capacity, with satisfactory temperature, why should it be called a 100 hp motor? Unreasonable demands for overload capacity in induction motors cannot be justified except on the theory that it affords protection in cases where motors have been poorly selected for a given service.

The equipment of a large establishment with induction motors with a motor load factor of, say 50 to 75 per cent, results in paying a high price for a margin of safety by increasing the first cost as well as decreasing the electrical efficiency and power-factor of the system, unless indeed the cost of power be an inconsiderable item.

The ideal result is attained when each motor is in its size and type and starting appliances most accurately adapted to the conditions which it is to meet.

G. E. Miller

The Testing Engineer

The three-fold capacity of the Testing Engineer as "an investigator, or a counsellor, as as a judge," brings out the functions of a new kind of engineer, who, as Dr. Dudley remarks in a prefatory paragraph, which has been omitted in the reproduction of his address in this issue of the Journal, "is becoming every day more and more prominent in the industrial world, and, as time progresses, is destined to play continually a more and more important part in the development of our civilization." Many of the points discussed in this address are not limited to a particular class of engineers, but deal with principles which concern all.

The element of human antagonism as an actuating force in engineering is presented in a way which will be new to many, especially to those who may have taken it for granted that an expert who is is acting in the interest of a client, particularly if the client be a manufacturing company, is so influenced that his expressed opinions are necessarily tainted by bias. An engineer who respects facts, who is true to the principles of his profession and who places integrity before success, is apt to find that rivalry and antagonism give incentives to effort when he hopes to attain a certain end which are lacking in an independent and abstract investigation. Commercial science thus has an advantage over pure science as an important element in the development of truth.

The discussion of the oft-recurring question of knowledge versus training in college contains an apt definition of men who can think as "men with minds so trained and so fitted with mental equipment that when unexpectedly and for the first time put in presence of a combination of circumstances, where action is necessary, they will know what to do and how to do it."

The comment on the proper "cast of mind" for successful engineering work, and the means of acquiring experience apply quite aptly to others besides Testing Engineers, and the last page contains some very practical discussion on the subject of engineering ethics.

Several articles which have recently appeared in the Journal, and which are apparently diverse in their subject matter and point of view, are alike in that they deal with different phases of engineering work, broadly considered. They have this in common,—Mr. Kerr, Col. Prout, Mr. Acheson and Dr. Dudley are all men who have attained eminence, and whose views and suggestions carry the weight which mature experience gives.

Charles F. Scott

The Value of an Engineering Apprenticeship Course

The young man just graduating from a college of engineering and about to commence an active pursuit of his chosen profession will do well to consider carefully the surest method by which to gain a substantial foothold. This is a crucial moment in his career, for upon it will depend in a great measure his ultimate advance in the profession.

He should come to a realization that it is beyond the scope of any educational institution to give within the comparatively short period of four years much more than a fundamental grounding in Physics, Mathematics and Chemistry, constituting a mere substructure upon which to add through years of service the knowledge to be gained only from the school of experience.

Many permit ambition for large pecuniary compensation to overrule their judgment with the result of early specialization, possibly in branches of the profession to which they are not adapted by natural inclination or otherwise. The young man who is wise enough to guard against the allurements of specialization until he obtains a broad general insight into the various problems confronting the mechanical and electrical engineer will become the higher paid specialist in the end.

The apprenticeship course of the Electric Company offers a rational method of supplementing a technical education with the needful practical experience. The development is gradual and systematic with every opportunity to gather engineering information adaptable to varied and manifold conditions, as well as experience in the actual design and manufacture of apparatus to fill these requirements. The apprentice learns to act with a purpose and to appreciate the value of directness of thought to the accomplishment of results. His ideas of the best way to do things are confirmed or refuted through actual contact and association with the men responsible for the conception and execution of the very best engineering practice.

The opportunities for association with young men representing the prominent educational institution of this and foreign countries, who have been brought together through the same motives and impulses, must be counted among the advantages of the apprenticeship course.

An advantage of beginning one's active work with a large company is found in the many and diversified lines in which advancement is possible. The various departments—manufacturing, designing, engineering, erecting, sales and executive—give the young man an opportunity to enter the field for which his aptitudes best fit him. If after a preliminary experience in one department it is found that he is best qualified for another, the transfer can often be effected, and the man has been the gainer by the broadened experience.

The value of such a course is probably best appreciated by those who began their work a dozen years ago, when present opportunities were not available.

Chas. E. Downton

Automatic and Semi-Automatic Synchronizing

The automatic synchronizer is proving to be a great help to central station operators, especially in rotary converter sub-stations, as it entirely eliminates the personal element of the operator. Mr. Baker's article in this issue of The Journal describes a typical installation of this apparatus.

There often arise cases, however, where there are no electrically operated switches for the synchronizer to operate, and for various reasons none can be installed. For such installations a semi-automatic system of synchronizing can be adopted, the automatic synchronizer being used instead of lamps or a synchroscope and actuating a signal when the proper moment for throwing in the switches by hand has arrived. In this method as in the automatic method with electrically operated switches, nothing is left to the judgment of the operator. The automatic synchronizer will not make the signal until: (1) The voltages are near enough the same; (2) The speeds are near enough the same. But it will make the signal the first time these conditions are fulfilled, and at an instant sufficiently ahead of synchronism to allow the attendant to close the switch at the exact point. When the difference in speeds of the machines is large, just within the safe limit of speed, the signal will be given at a greater interval of time ahead of the synchronous point than when the difference is slight.

As an example, assume that it takes an operator one-half a second to receive the signal and throw in the switch, and that the safe difference of speed is equal to one synchronous period in five seconds. As soon as the voltages are within a safe percentage and the speeds differ by one synchronizing period per five seconds the signal will appear when the incoming machine is thirty-six degrees before true synchronism. When the synchronizing periods are twenty-five seconds, the signal will appear about seven degrees ahead. Thus in each case the operator would have the same length of time to close the switch.

The signal operated should be one having the quickest possible time element. Thus an incandescent lamp would not be as good as a bell or some mechanical device such as a tell-tale indicator. In either case the automatic synchronizer would have to be adjusted to suit the time element of the indicator plus that of the operator.

PAUL MACGAHAN

The American Institute of Electrical Engineers

The October issue of the proceedings of the Institute contain a new feature which is of interest in itself and is significant of the new attitude which the Institute has assumed toward its membership. The new feature is in the nature of a bulletin giving current electrical and engineering news, personal items, editorial comment on various matters of interest, reports on the activities of the various Institute committees and the like, and reports and announcements respecting the Institute branches. The monthly proceedings therefore not only contain a list of technical and engineering papers with discussions thereon but in addition to these there is something up-to-date and of current interest. This gives a new life and spirit and a lively interest which will not only be greatly appreciated by the members at large but will bring them into closer touch with Institute affairs.

The reappointment of the High-Tension Transmission Committee and the appointment of a new committee to deal with telephony, and the activity of various Institute branches all indicated a healthy and progressive condition. The Institute will shortly move into its new quarters in the new Engineers' Building, which will increase its facilities and should mark the beginning of a new era in its influence and usefulness.

The membership of the Institute has increased more than threefold during the last five years. There is no reason why this growth should not continue. This growth will certainly continue as those who are eligible but are not members come to appreciate the work which the Institute is doing and the value that it may be to them individually.

CHAS. F. SCOTT.

APPLICATION OF THE PRINCIPAL TYPES OF POLYPHASE INDUCTION MOTORS*

W. EDGAR REED

IN ORDER to choose the proper motor for a given service, it is necessary to know the requirements and the characteristics of motors which may be used for this work. When these are known the motor that is best suited for a given class of work can be determined.

The principal types of polyphase induction motors may, for convenience in applying them, be classified according to their operating characteristics as constant and variable speed motors. The most important characteristics to be considered in making applications are the speed-torque curve (or automatic variation of speed for different torques or horsepower outputs of the motor), the maximum starting torque and corresponding current, the rating or load the motor will carry for a given time with satisfactory temperature rise, and the efficiency and power-factor under these different conditions.

SPEED-TORQUE CURVES OF CONSTANT AND VARIABLE SPEED MOTORS

The characteristic speed-torque curve of the polyphase induction motor is shown in Fig. 1, curve *a*, from which it can be seen that the speed drops gradually with increase of torque from synchronism or constant speed until the maximum (pull-out) torque is reached. Any increase in load cannot then be overcome by torque developed by the motor, consequently both speed and torque diminish until the motor stops. The intersection of the speed-torque curve with the axis of torque will be of value of the maximum starting torque. The percentage drop from constant speed is the per cent slip of the motor. The full-load percentage slip of the motor is frequently referred to simply as "slip." The slip is proportional to the copper loss in the rotor, thus four per cent slip means a copper loss in the rotor of four per cent. An increase in slip, therefore, means a decrease in efficiency.

The so-called constant speed type of motor is one that has the minimum slip and therefore the best speed regulation and efficiency for various loads. The average slip for large motors will not exceed a couple of per cent and for small motors will be greater as the horse-power size diminishes, reaching five to six per cent for motors of small size. If speed regulation were the only feature to be taken care of, the slip could be made lower than it generally is for the average constant speed motor, but good starting torque and low starting current in the line depend directly upon the slip. For this reason in order to obtain a fairly good starting torque and to limit the maximum starting current a greater slip is allowed than would be necessary to obtain small starting torque, large starting current, and the best possible speed regulation. There are some applications, however, where low starting torque only is required, such as motor-generators which are started up unloaded or from the generator side, for motors operating centrifugal pumps, air compressors, etc. In these and similar cases the speed regulation and efficiency can be made the very best. See Fig. 1, curve *a*. But the average constant speed motor, see curve *b*, is required to develop a starting torque of from one and one-fourth to two times full-load torque, and

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*Based on a lecture delivered before the Electric Club.

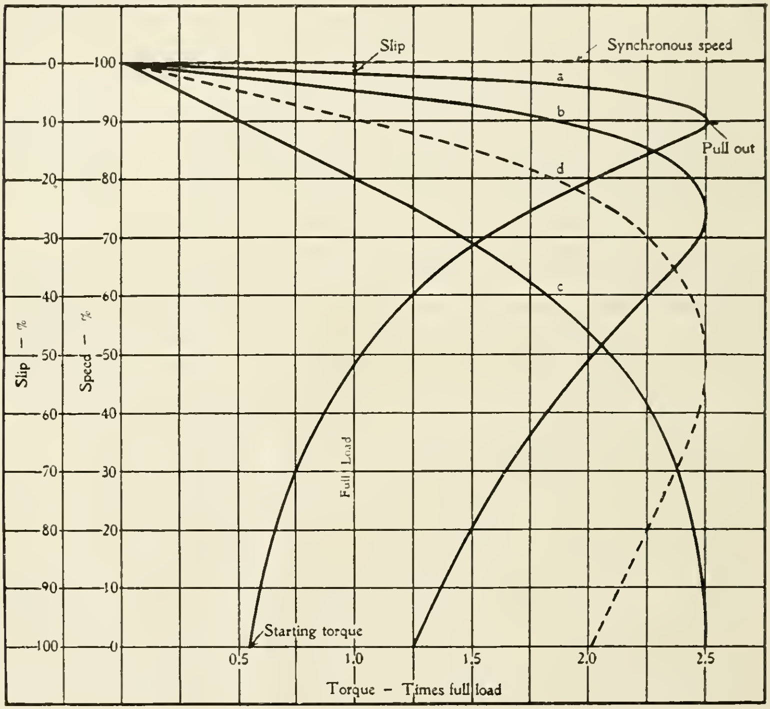

FIG. I

the corresponding starting current in the motor may vary from approximately four and one-half to seven times full-load current (or three to three and one-half times full-load current for full-load torque may be obtained by applying suitable reduced voltages). Motors which fulfill these requirements are made with a speed regulation that is satisfactory for nearly all classes of constant speed work. The maximum running torque of the average constant speed induction motor may vary from approximately two and one-fourth to three times full-load torque, depending upon the size of motor. This is about fifty per cent greater running than the starting torque.

The variable speed motor* has very large slip and hence a large variation in speed for changes in torque, or in other words the poorest speed regulation and low efficiency, other conditions remaining the same. It develops the maximum torque at starting with minimum starting current. The value of maximum and starting torque will be at the intersection of the speed-torque curve with the axis of torque or at zero speed, as shown in Fig. 2, curve *c*. Motors of this type are sometimes designed to have a speed-torque curve that approaches a straight line. These motors have been frequently called the "straight line motors." The average motor of this type is designed to develop a starting torque of not less than two and one-half times full-load torque and the starting current taken by the motor will be approximately four times full-load amperes (or one and one-half times full-load amperes for full-load torque if reduced voltage is applied).

The slip, starting torque and starting current of induction motors may be varied by changing the rotor resistance. An increase in resistance within limits increases the slip and starting torque and diminishes the starting current. The maximum torque is practically unchanged by variations in rotor resistance. Constant speed motors, as shown by curve *a*, Fig. 1, may be changed in this way to motors having the speed, curve *c*, or intermediate curves, such as *d*. Some of the intermediate curves are comparable to the speed-torque curves of direct-current compound-wound motors which have speed characteristics intermediate between the shunt and series motors, and induction motors having these characteristics can in a general way be applied to work similar to that for which compound motors are used.

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*"Variable speed motor" here refers to motors whose speed varies automatically with the torque and horse power. Their speed-torgue curve differs from that of the shunt-wound direct-current adjustable speed motor which is sometimes also called a "variable speed motor."

RATINGS

Constant speed motors are generally rated so that they will carry normal load continuously with a rise in the temperature of forty degrees C., or less, twenty-five per cent over-load continuously, with a rise of sixty degrees, or less, and fifty per cent over-load for one hour with a rise of fifty degrees, or less, all the temperatures being measured by the thermometer method.

Variable speed motors are generally operated under continually changing loads and the best way to determine the size of motor required for a service is to determine the average losses for a given length of time or cycle of operations. A size of motor can then be chosen that will operate with these average losses. For this reason variable speed motors for industrial work are rated like series railway motors, that is, at a maximum horse-power for a one-half or one hour run with a temperature rise of forty, sixty or any other degree C. rise by thermometer. Curves can also be made which show the lengths of time a motor will carry different loads with a given temperature rise. These motors are given a number instead of a horse-power rating, as is done with railway motors.

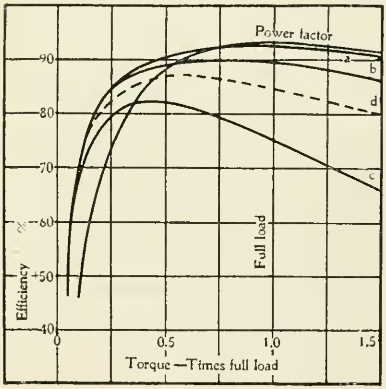

FIG. 2

EFFICIENCY

Constant speed motors with a minimum slip have the highest efficiency. With increased slip and secondary resistance the efficiency diminishes on account of the increased secondary losses. The efficiency of variable speed motors is lower, other conditions remaining the same, on account of their large slip and secondary losses. The curves *a, b, c* and *d* in Fig. 2 show the changes in efficiency with different rotor resistances. These efficiencies correspond to the similarly marked speed curves in Fig. 1.

POWER-FACTORS

The power-factor at light load is very low, but increases rapidly with the load, and is generally very good for the constant speed motor at full-load, as shown by the power-factor curve in Fig. 2. The power-factor when starting with load may reach forty to sixty per cent. The power-factor curve of the variable speed motor follows the general form of that for the constant speed motor but is generally somewhat lower, especially for light loads. When severe starting conditions, requiring several times full-load current at a low power-factor exist, their effect upon the supply circuit should be considered in making applications.

TYPES OF ROTOR WINDINGS

Polyphase motors are generally of the squirrel cage (short-circuited rotor) or the slip ring (wound rotor) type. The squirrel cage motor is the simplest mechanically. There is nothing to get out of order and its operation is entirely automatic. There are only a few volts generated in the secondary winding, and no trouble is experienced with insulation breakdowns. The motor, therefore, requires very little attention and expense for maintenance.

The starting current of a squirrel cage motor may be decreased by applying a lower voltage than normal, the torque, however, is proportional to the square of the voltage applied, so that the application of this method is rather limited unless the torque of the motor under normal voltage is very high. The lowest suitable voltage for the required starting torque should be used, however, as the shocks and strains upon apparatus connected to the motor are in this way also reduced.

The wound rotor is more complicated and difficult to make on account of the winding and insulation for higher voltages, sliding contacts and variable rotor resistances which must be inserted manually or automatically.

By using a variable rotor resistance in connection with a slip ring motor there are obtained some of the advantages of the high resistance rotor at starting and the low resistance rotor when running. A starting torque equivalent to full-load running torque can be obtained with a current only a little greater than full-load current, and the power-factor still be the same as under running conditions. This is a most important feature, especially when the starting current may effect the supply circuit. The efficiency will also be high under running conditions.

Different rotor resistances can be used for obtaining variable adjustable speed motors. The efficiency is lowered, however, as the speed is reduced, and this should be considered in making applications. For example, half-speed would mean fifty per cent loss in the rotor resistance and the efficienty of the motor would be less than fifty per cent. Also under these conditions the speed is constant only for a given torque or horse-power, and will change as soon as the torque required changes. The speed will follow speed curves, similar to those shown in Fig. 1, for different torques and there will be greater variation in speed for the high than the low resistance rotor.

APPLICATIONS

The variable speed motor should be used when frequent severe starts are necessary and the period of operation is short, and where variations in torque and speed are great,—for example, on cranes, elevators, hoists, railways, roller beds, bending rolls, reciprocating machine tools, punches, shears, etc. For elevator, or similar work where quick, frequent starts and stops are necessary, motors having a minimum inertia of rotating parts should be used. In this case it is advisable to use motors of the slowest speed and lightest weight of rotor that will give satisfactory operation. Although the efficiency of this motor at full-load is less than the constant speed motor, yet as the motor runs only a short time at full-load, this is not of as great importance as the efficiency when starting, which is higher than for the constant speed motor. Variable speed motors are also used for starting rotary converters, synchronous motors, etc., where they must develop exceedingly heavy torques for a very short time.

Constant speed motors are generally used for that class of service which requires fairly constant power for a long period, good speed regulation, infrequent starting and only average starting torque, such as driving line shafting, high and low speed centrifugal and reciprocating pumps, air compressors, blowers, fans, rotary motion machine tools, wood working machinery, lathes, boring mills, circular and band saws, motor-generator sets, frequency changers, continuous running constant loaded machinery, etc.

In general, the short-circuited type of rotor should be used when the motor is small compared with the size of the generating station; when the voltage regulation of the system would not be effected by the starting current required by large motors; when the starting conditions are not frequent or severe; when the motor is not accessible for frequent inspection and where simplicity is of great importance.

The wound rotor should be used when the motor is large compared with the capacity of the generating station; when good voltage regulation is necessary; when frequent starting is required and where large starting current would seriously affect, or be undesirable to, the system; for work at reduced speeds or where fairly heavy loads must be brought up to speed gradually.

Note.—The following classification of Westinghouse polyphase induction motors was given by Mr. Reed in his lecture before the Electric Club. This may be of interest as the various types of motors are given according to their trade designation.

		Types.	Sizes.
Constant Speed	Squirrel Cage Rotor	C CX CCL	All
	Wound Rotor	F FX HF	All
		HX	60 cycle motors up to 50 h. p.
Variable Speed	Squirrel Cage Rotor	C, crane and starting	Generally motors that can be built in the 75 h.p. frame and smaller
	Wound Rotor	F FX HF	All

The HX type of motor has resistances mounted on the end of the rotor shaft outside the bearing brackets. These resistances turn with the rotor and slip rings are not necessary. A plunger is used for gradually cutting the resistances out of the circuits.

The F and FX types of motor are fitted with slip rings mounted outside the brackets. These are connected to external resistances which are gradually cut out of circuit by a controller.

The HF type of motor is similar to the ones just given except the slip rings are mounted inside the brackets. A device is used on the larger sizes of motors for short-circuiting the winding when the resistance is cut out so that no current will flow through the collector rings and brushes.

HF constant speed motors are supplied with resistances having sufficient capacity for starting only. The variable speed motors of this type have resistances of greater capacity for running continuously at reduced speeds.

THE TESTING ENGINEER

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The following article is from one of a series of presidential addresses delivered by Dr. Dudley before the American Society for Testing Materials, at its various annual meetings. The series has thus far embraced three addresses and it is expected that a fourth one will be forthcoming at a subsequent meeting. All of these addresses refer in some way to the testing of materials. The first address was entitled "The Making of Specifications for Materials," the second, "The Influence of Specifications on Commercial Products," the third one, slightly condensed, is given below, and the fourth will take up some other phase of the same subject, probably, "The Enforcement of Specifications." Dr. Dudley has been engaged for thirty years in this line of work and has accumulated a large amount of experience on the subject which he has attempted to treat. (Ed.)

THE field which the Testing Engineer occupies, and the cause to which his loyalty is due, may perhaps wisely claim a few moments' attention.

The Testing Engineer acts in a three-fold capacity. He is either an investigator, or a counsellor, or a judge. He is finding out new truths, he is protecting the interests of his client the producer, or he is determining by his tests that contracts are being fulfilled, or specifications lived up to, in the interests of his client the consumer. While all three forms of the Testing Engineer may be and often are engaged in research, in investigating a knotty problem, or devising means of demonstrating a point, it is perhaps more commonly the work of what may be called the "unattached Testing Engineer" to make investigations. The professors in colleges, especially those having a genius for experiment, and indeed independent investigators, who, as the result of business shrewdness or by good fortune, are so situated that they are not compelled to struggle for an existence, are continually adding to the sum of human knowledge by their tests and experiments while laboring in this field. They have no clients to satisfy, no employer's interests to defend, and no antagonisms to overcome except perchance the unwillingness of nature to yield up her secrets. Their loyalty is to the truth alone; their stimulus, their zeal for knowledge, and their reward, the approbation of their fellows. These seem to be almost ideal conditions for securing the truth, and it would seem as though results obtained by such experimenters, or Testing Engineers, and under such conditions, ought to be accepted and acted on without question. But we venture to suggest that there is one desirable, not to say essential element, in the search for truth, that is lacking in the conditions outlined above. This is the element of human antagonism. Perhaps an example will best make the point clear. The subject for investigation we will say is a method for determining phosphorus in steel. The professor, or independent investigator, makes his studies and experiments, and publishes his results. During the whole investigation he has been actuated by no desires, except to get at the truth. There has been no temptation, except perhaps the desire to finish the investigation, to stimulate him to neglect any essential point, to give any results or draw any conclusions that the most rigid interpretation of the facts would not warrant, and hence so far as accuracy is concerned, it would appear as though no question should be raised. And yet, so great is our belief in the value of human antagonism, where the truth is involved, that we cannot help saying that we would prefer a method which resulted from the contentions of two chemists, the one of whom was the employee of a consumer and who was trying to make out that the sample on which they were both working contained more phosphorus than the specifications allowed; and the other of whom was the employee of the producer, and who was trying to show that the phosphorus in the sample was below the requirements of the specifications, there being a large commercial transaction involved in the result. We cannot help feeling that every point in the method would receive much more severe criticism, and consequently if it survived would be much more worthy of confidence under these conditions, than if it were brought out by a single experimenter making investigations for the sake of publishing them. So greatly does the legal fraternity rely on the element of human antagonism as an essential feature in the development of truth, that we are entirely safe in saying that the whole structure of legal procedure is based on this foundation.

It may not be amiss here also to quote from one of our instructors in chemistry, who had reached the philosophic age, and who in a very dry way used to say that during his active work he had tested many published methods in analytical chemistry, which, for some reason, not necessary to explain, always apparently gave better results in the hands of those who devised them than he was ever able to get from them. We fancy it hardly needs saying that in this matter there is no intention of questioning the integrity or reliability of invesigators who are studying the truth for truth's sake. The point we had in mind was to suggest the thought that perhaps those who are accustomed to glorify pure science may have overlooked one fairly important element in the development of truth.

As already indicated, the field of work of the Testing Engineer in the industrial world seems to be either to find out new things, or to protect the interests of the producer or consumer. And there are three kinds of testing engineers to occupy these two fields, viz., the unattached engineer, the consumer's engineer and the producer's engineer. At first, there were apparently only two kinds of testing engineers, viz., the unattached and the consumer's. But it did not take long after consumers began to study and test materials and prepare specifications, before the producers found it necessary to protect their interests and defend their materials by means of testing engineers in their own employ.

It is perhaps hardly necessary to say that in this, our analysis of the scope and field of the Testing Engineer, we have not forgotten the various inspection bureaus and testing laboratories which are doing such excellent work in various parts of the country. As we understand the matter, these organizations, while perhaps not strictly covered by the definitions given, in that they do not derive their continuous sustenance in such a way as the unattached testing engineers, nor in the same way as those who defend the interests of the consumer or the producer, and in that they have an independent organization, and owe loyalty only where it is paid for; yet in a certain sense these independent organizations do perform exactly the same functions as the three classes of testing engineers which we have described. Any one of them will make investigations either in the interests of a client or for the sake of the truth alone; any one of them will temporarily, or continuously, if the retainer be sufficient, defend and care for the interests of a consumer, or will render a like service for a producer, provided, of course, that the interests of the two are not antagonistic at the same time. So that we cannot help feeling that the three kinds of testing engineers mentioned, the unattached, the producer's and the consumer's, fairly well cover the field.

What now shall be the cast of mind, and what the mental equipment of the Testing Engineer? Upon the first of these topics, it is difficult to say much that is positive. It is perhaps easier to say what kind of mind will not succeed in this branch of engineering, than to say what the positive requirements of a successful testing engineer are. We will perhaps all agree that he should be independent, self-reliant, gifted with the power of analysis of facts, as well as with the power of drawing conclusions from the data at hand. He should be ingenious in devising methods to demonstrate the points at issue, and a careful observer of data. He must keep himself free from bias or prejudice, and take especial pains that he does not deceive himself. He should be fond of experiment and have a genius for it. Many times during our nearly thirty years' attempt to do something in the line of the work of a testing engineer, we have had occasion to paraphrase the Latin apothegem and say, "experimenters are born, not made." He should keep constantly in mind the end to which his experiments tend, and understand clearly the effect of every step in the progress of his tests, and its influence on the final result. Above all, he should be a thinker. No man who, when a problem is presented to him, simply searches his memory for whatever he may have learned in the schools, or have perchance picked up in his reading, which bears on his problem, has any especial call to be a testing engineer. We are quite ready to allow that the power of seeing analogies between your own problem, and one that some one else has had, and perchance successfully solved, is a legitimate and useful, not to say time-saving habit of mind, but the point we want to make is that the one who habitually and continuously approaches every problem through memory, or by studying up what others have done, is far lesss likely to succeed as a testing engineer, than one who habitually attacks a problem by an analysis of its elements.

But it may be urged, if experimenters are born, not made, and if so much depends on cast and habit of mind, what can the schools do in the way of training and furnishing mental equipment to produce successful testing engineers? We answer much, every way. While it is probably not possible for any school to make a thinker out of a dreamer, or a successful experimenter out of a numskull, we still claim that, given an ordinary fair mental endowment, it is possible for the schools to make successful testing engineers, or to spoil the material they start with.

It hardly comes within the sphere of this paper, or coincides with our present purpose, to say anything about the curriculum of studies best calculated to fit a man to be a successful testing engineer. This is neither the time nor the place for such a paper, although we may possibly say something a little later about the self-education of the one who expects to spend his energy in this field of work. At this place we will, however, touch upon one or two points in connection with methods of teaching. Our observation of what the world wants to-day, not only in the field and work of testing engineers, but also in almost every other field, is men who can think; men with minds so trained and so fitted with mental equipment, that when unexpectedly and for the first time put in presence of a combination of circumstances, where action is necessary, they will know what to do and how to do it. This may look like a very severe dictum to apply to recent graduates, with their limited experience and small accumulation of facts, and yet we cannot help feeling that in some degree this dictum may legitimately be applied even to them, and that if they have been properly trained by the schools they will show in some measure a capacity for meeting unexpected and unforseen emergencies. But it may be asked, what teaching and what training leads to the development of this capacity? We answer, that while it is undoubtedly true that the mental characteristics of the student himself are a most important factor, and that it is clearly impossible to make thinkers of every student in the class, yet as we understand the matter, that teaching which brings out and keeps prominent before the mind of the student the principles underlying the theme which is under consideration, be the subject of study whatever it may, rather than that teaching which fills the mind of the student with methods, with manipulation, and with accumulated information, embracing a taste of many subjects, will have a tendency to develop the kind of mind we are looking for. A somewhat extensive acquaintance with recent graduates from the chemical schools for a number of years past, has led us to fear that methods, manipulation and accumulated information were given undue prominence, and that principles and reasons why were not sufficiently insisted upon. We are clearly of the opinion that the schools truly desire to furnish what is wanted, and that the situation as we seem to find it, is due to the effort on the part of the schools to turn out their graduates, fitted to at once begin to earn a livelihood or perchance to take charge of independent work. We are compelled to say that, while the motive seems praiseworthy, and a legitimate yielding to the demands of the times, we cannot help feeling that many a graduate will, under such tutelage, fail to reach the success which, with a different method, would have been legitimately in his grasp.

Perhaps an illustration will make clear the difference in methods of teaching which we have in mind. Not long ago we separately asked three recent graduates, each one from a different, entirely reputable school, why nitric acid is used to dissolve steel, when one is going to determine the phosphorus. Why not use some other acid just as well? Two of the three replied that they supposed that nitric acid was a good solvent for steel, and they knew of no reason why any other acid that would dissolve the steel would not do as well. The third answered that in order to take the next step in the process, it was essential that the phosphorus should exist as ortho-phosphoric acid, and that nitric acid being an oxidizing agent would bring the phosphorus to that condition. Now each of these three recent graduates knew how to determine phosphorus in steel, and as a matter of fact each of them had done it in an entirely acceptable manner and under check for six months or more in my own laboratory. All three of them were familiar with the method and with the manipulation. But as we look at it only one of them had been properly taught. He not only knew the method and the manipulation, but he also knew the reasons why, and the principles underlying the method. One of my assistants put the matter very forcibly. He said: "The chemist who knows methods and manipulation gets along swimmingly as long as everything goes well, and perhaps turns out more work in a day than a thinking chemist who understands the reason why for very step in his analysis, but let a difficulty arise, and your method chemist is absolutely lost."

There is another phase of this case which is perhaps worthy of a moment's notice. Given two young men of equal ability, and let both of them go through good technical schools, both graduating as chemists, or as mining, mechanical, civil or electrical engineers. The one during his course of study has covered much ground, has stored his mind with facts, has learned carefully, and well, the methods and manipulation required in the branch chosen. The other has not covered so much ground, but every bit of information that he has he thoroughly understands; he has acquired principles rather than a large array of facts, and he knows the reason why. Let now these two begin work after graduation in the same place, and we are ready to confess that the former will make the best showing, and progress the more rapidly for the first year or two, but if our observation is worth anything, the latter will distance his competitor at the end of ten years.

The mental equipment which the schools furnish is only a fraction of that needed by the Testing Engineer, especially if he happens to have it as his field of work to defend the interests of a great consumer. It is legitimate and reasonably to be expected that the schools should teach a young man how to learn, and should start him in a number of subjects; but his real education comes later. We often say to our young men that the two things that a recent graduate needs most are experience and acquaintance. Under the head of experience, we comprehend the arranging of the information already acquired, so that each part will have its due, and only its due prominence, the accumulation of additional information, either by reading, by close and continuous study of his main theme or related branches—we fancy it almost goes without saying that the man who expects to reach even moderate sucess as a Testing Engineer, must study harder the first five or ten years after graduation, than he did at any time while in school—we say a man must accumulate experience by arranging the information already acquired, by reading, by study, and actual contact with industrial processes, and with the world's work, in every possible detail, and above all, a man must acquire experience by actual wrestling with problems that may be committed to his care. It is apparently not essential, in order to gain experience, that one should successfully solve his problems. Faraday was accustomed to say that he actually learned more by his failures, than from his successes. We cannot, we think, too emphatically insist on the importance to the Testing Engineer, of self-education, of the broadening of his field of knowledge and of the acquisition of facts. The Testing Engineer should be an omnivorous student. Nothing too trivial to interest him, nothing too remote from his present line of work to make a legitimate demand on his attention should opportunity offer. The schools, if they have done their duty, have given you a more or less trained mind, and have taught you how to learn. It is your own fault if you do not broaden every day. You can never tell what moment you will need, and badly need, some out of the way fact. Store them up against that time of need.

A brief illustration will perhaps emphasize the importance to the Testing Engineer of familiarity with the minute details of industrial processes. A couple of years ago, while the finishing cut was being taken on a steel driving axle in a lathe, the operator noticed in the freshly cut surface what appeared to be a small flaw. On testing this with a pin, the pin disappeared, and quite a length of fine wire followed it. On taking out a transverse slice of the axle at this point, a cavity was found in the metal which would hold half a pint or more. The walls of the cavity were perfectly clean and bright, and but for the fact that the finishing cut just happened to open up the cavity a trifle, its presence would not have been suspected, and the axle would have gone into service. It is perhaps safe to say that one-quarter or possibly one-third of the cross sectional area of the axle was embraced in the cavity. We have seen a number of such cases, and unfortuniately the phenomenon is not too rare. Almost any practical steel maker, when asked for the cause of such a cavity in what is apparently a solid piece of metal, would probably laconically answer, "careless heater." In order to understand this statement, it is necessary to say that many driving axles even when they are finished are about eleven inches in diameter, and that the bloom from which they are forged is considerably larger. If now such a bloom when cold is put into a hot furnace, the outside layers get hot long before the inside has begun to raise much in temperature. A severe strain, due to the greater expansion of the outside layers, is accordingly set up, which strain is enough occasionally to actually rupture the inside. Subsequent forging opens out this rupture into a cavity. The rupture is usually accompanied by a noise like a pistol shot. The unfortunate part of the business is that there being a number of blooms in the furnace at one time, it is impossible to tell which one has yielded to the strain. As would be expected, the larger the axle the more common this defect, and we know of one large railroad that bores a two-inch hole through every axle over eight inches in diameter that is destined for passenger service. The boring of the hole enables the cavity to be discovered, either by the behavior of the drill, or by sight examination's after the hole is finished. It is interesting to know that something over two per cent. of all axles bored are defective in this way.

One or two points more, and we have finished. It may seem an idle question, but it is certainly an interesting one, as to which of the three kinds of Testing Engineers has the most attractive field of work. The unattached testing engineer certainly has the greatest freedom, but at the same time the least stimulus. The producer's Testing Engineer undoubtedly has the best financial reward, but at the same time the narrower field. He has, however, the advantage of concentration, and as almost every modern industry has scores of unsolved problems connected with it, there is no reason, if he will work, why he should not achieve a great success. On the other hand, the consumer's Testing Engineer has unquestionably the broader field, the greater chance for initiative, and perhaps more important than all, an opportunity to study the behavior of materials in actual service. This last item gives him a great advantage. The behavior in service is unquestionably the ultimate criterion by which every industrial product must be judged, and by whose decision, sooner or later, it must stand or fall. Undoubtedly, individual characteristics are a legitimate element in the choice, but our counsel would be to every ambitious Testing Engineer, to get as near to the service as possible, and to this end to make some sacrifices if necessary, to secure a position with a consumer.

And this brings us to another point. We have many times heard complaints of the dullness and unsatisfactoriness of spending one's days and weeks in making routine tests. We are compelled to say that we do not understand this. It is one of our sincere regrets that we are no longer able to do routine work. To us there is genuine pleasure in seeing how the test comes out in each individual case, although we may have performed the same operation over and over again. Moreover, there is scarcely a method in use to-day, either in chemical or physical testing, that is not capable of improvement, either in accuracy or speed, or both, and what better opportunity for suggestions could be desired than is furnished while the hands are busy doing that which from long practice they do almost automatically, and with the attention necessarily directed to the subject in hand, leaving the mind almost free to dwell on possible changes leading to progress. Some of our very best thoughts have come to us while engaged in routine work. One is very near to Nature's heart when making tests, even routine tests, and if his mind at such times is alert and receptive she will not infrequently give him a hint or disclose a fraction of some of her secrets to his view.

There is one more phase of the work of the Testing Engineer which will perhaps bear a few words, and that is the relation between the Testing Engineer and those whose material he is testing. This is unquestionably a delicate subject, one that we would all gladly feel did not need discussion or comment, and yet one that is constantly thrusting itself into prominence, in some form. For the honor of human nature, it is gratifying to be able to put on record that during nearly thirty years of almost constant testing, only once have direct financial consideration been urged upon us to influence our verdict in regard to material. On the other hand, we have heard representatives of entirely reputable business organizations say openly, "It costs us something to sell our goods, and it is entirely immaterial to us whether this money goes to our selling agents, or to the representatives of the consumers." And this is not the worst phase of the matter. It is well known that the representatives of consumers, who act in some sense in the capacity of Testing Engineers, in that their opinion or decision determines the placing of orders, not only accept substantial considerations from producers, but even demand them, if not openly, at least indirectly. The subject is one of which much might be said. An hour could readily be filled in narrating incidents and portraying the forms in which the hydra-headed monster, graft, manifests itself. We are confident that neither side is free from blame: we are equally confident that strict, open honesty is the only safe course. It may not be amiss to add that so insidious are the forms in which this evil manifests itself, that, in the word of the Scripture, they would at times deceive the very elect, and while it is not possible to discuss these matters, without raising interminable questions of casuistry and metaphysics, it is possible to so act as to have the continuous approval of a good, clean conscience. No universal rule can be given. Each one in a sense must be a law unto himself. Perhaps the best every-day working rule for young Testing Engineers is, do nothing you would not be willing to talk over with your employer, even in the presence of the other party. It is sometimes a bit hard to resist and say "no," but of one thing be sure—every departure from strict integrity will, sooner or later, return to plague you, and should your actions ultimately result in your downfall, from none will you get less sympathy than from those who may have contributed to your disaster.

THE STANDARDIZING LABORATORY—I

A TESTING CIRCUIT FOR ALTERNATING-CURRENT WATTMETERS

H. B. TAYLOR

AN important test in the calibration of wattmeters is the determination of their accuracy in measuring loads having low power-factors. The circuit which is intended to be used in testing wattmeters should be arranged so that the meter being tested can be compared at low power-factors with a standard which is known to be correct at all power-factors.

INDUCTIVE LOAD

Fairly satisfactory tests can be made by using choke coils or some other load having a low power-factor, but to load in that way over a wide range of current and have a reasonable control over the power-factor of any given load is not easy, even when the power-factor need not be lower than 0.6 or 0.7 and would usually be practicable only for lagging currents.

LOW POWER-FACTOR CONDITIONS FROM POLYPHASE CIRCUIT

When a polyphase circuit is available a better plan can be followed. The meter can be tested under conditions of low power-factor without the use of a load which would actually produce that condition on the line. The view in Fig. 1 and the diagram of connections in Fig. 2 show an arrangement which has been used on experimental work covering complete data on wattmeters and also on various polyphase tests.

CHOICE OF CIRCUITS

In the method here given a three-wire circuit is used. The power supplied may be either two-phase or three-phase. There is little choice between them as far as convenience is concerned. One point worth considering when a machine is to be selected for this work, as when a small rotary converter or motor-generator is to be installed for testing wattmeters exclusively, is that a three-phase line can be run to the test circuit directly from the machine, while if a two-phase machine with closed-coil winding is used it is necessary to put a transformer in at least one phase in order that the two phases can be combined on the three-wire circuit. By referring to the diagram it can be seen that the series coils of the wattmeters are connected in the middle line of the circuit and there is a lamp board in each of the other sides. A smaller auxiliary lamp board with adjustable resistances and switches arranged for series or multiple connection of lamps can be connected to either of the main lamp boards. Current is supplied to the shunt circuit through a two-point plug which fits any two of the points in the three-point receptacle. This plug is connected to the testing circuits by means of flexible leads and can be used as a reversing switch. The three points of the receptacle connect to the three sides of the main line.

INDUCTION REGULATOR

A similar plug and receptacle are provided for switching on the primary of an induction regulator. This regulator is made on the same principle as the Stillwell regulator, but has its secondary winding on a drum which can be revolved through a semi-circle. This gives gradual changes from maximum secondary voltage in one direction to maximum in the opposite direction. It is used as a voltage regulator or as a phase-shifter, depending on whether the primary is connected to the same phase as the meter shunts or to another phase.

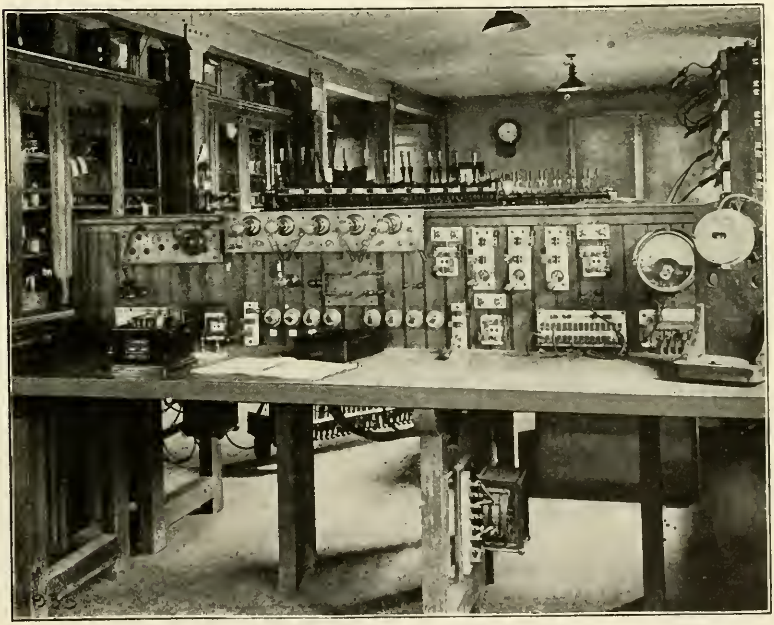

FIG. 1—VIEW OF WATT-METER TEST TABLE

TRANSFORMERS

A small transformer with taps for various voltages is placed on the shunt circuit. This can be an auto-transformer, but is preferably one with separate primary and secondary windings. The objection to the auto-transformer or to omitting the transformer entirely is that there would then be more opportunity for short-circuits by bringing the wrong end of the shunt circuit into contact with the series circuit when not carefully handled. The series auto-transformer is put in simply to economize power in testing heavy current meters. A small current in the lamp boards will give a heavy current in the series coils. This transformer is cut in or out by means of the plug switches and is used only when the current required is more than ten amperes.

PHASE RELATIONS

With the series current all passing through one lamp board and the shunt plugged in on the pair of wires that supply the same lamp board, the connection is the same as on any single-phase circuit. The calibration at what may be considered unity power-factor is made with this connection using a bank of incandescent lamps as load. The actual power-factor is between 0.997 and 0.998. If the circuit is two-phase, a power-factor approximately zero can be obtained by connecting the shunt circuit to the second phase, leaving the series circuit as it was. To

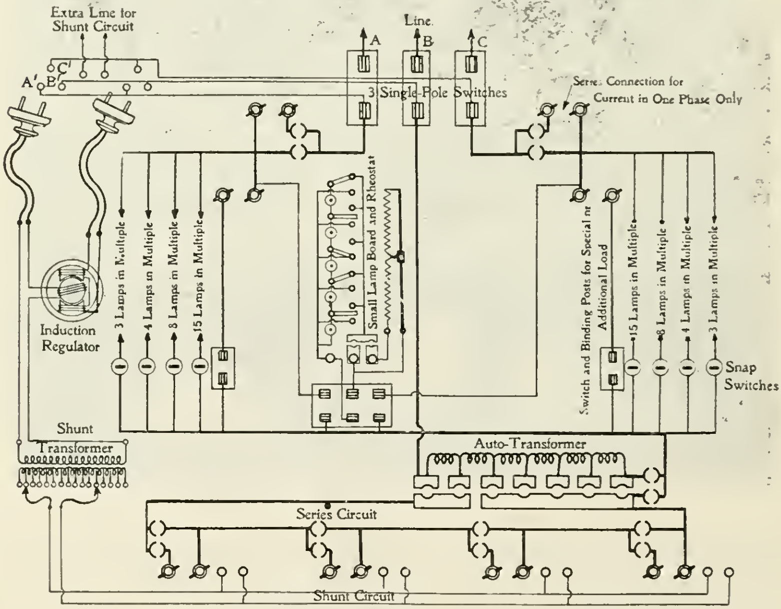

FIG. 2—CONNECTIONS OF WATT-METER TEST TABLE

one not familiar with wattmeters it might seem that a test at zero power-factor would be so far from a practical working condition as to be of little interest. As a matter of fact the performance of a wattmeter at zero power-factor is a very reliable indication as to what it will do at power-factors between that and unity. It is, moreover, a simple test to make as there is no necessity for reading voltage or current accurately.

Integrating induction wattmeters, which are always provided with a device for adjusting to low power-factors, can be adjusted with much greater facility at zero power-factor than at any other, because they do not have to be "timed." The usual adjustment is to make the disc stand still when the standard reads zero at an apparent load about equal to the full rated load. If the load is on the side indicated by the letters *BC*, (Fig. 2) and the shunt plug is connected to *B′ C′* the power-factor is about unity. Transferring the plug to *A′ B′* gives about zero power-factor. To make the power-factor exactly zero, a little current from the same phase as the shunt can be obtained with the series, current BC to produce a resultant in quadrature with the voltage *A′ B′*. The small lamp board is connected to the AB side for this purpose. If the difference in phase between shunt voltage and series current is greater than ninety degrees a proper adjustment of current in the small lamp board will give the required result. If less than ninety degrees any current in the small lamp board will raise the power-factor instead of lowering it. In that event it is necessary to reverse one phase of the main circuit. This is shown graphically in Fig. 3. The phase relation between shunt voltage and the current in the lamp board BC is shown by the lines E and I_{BC}. The angle of lag of I_{BC}, behind E being more than ninety degrees, some current, I_{AB}, combined with I_{BC}, will give a resultant current, I, in quadrature with E. If I_{BC} lagged less than ninety degrees behind E, the addition of any current in the direction of I_{AB} would reduce the angle still further, thereby increasing the power-factor. To illustrate the latter point, the current *I′*, with less than ninety degrees lag, is combined with I_{AB}. The projection of E upon the resultant cur-

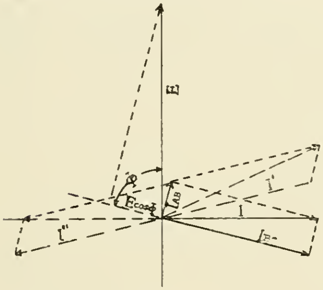

FIG. 3

rent vector is greater than upon *I′*. Reversing *I′* gives it the position *I″* in which it readily combines with a current in the direction IAB to produce a resultant in quadrature with E. On first glance at the diagram, this looks like a change from lagging to leading current, but the adjustment is required only at zero power-factor, where there is no difference between lag and lead. If there are special conditions making it necessary to consider direction of current, E can be reversed at the shunt plug without changing IAB.

Loads at any power-factor, lagging or leading current, can be obtained by varying the proportion of lamps on the two boards. The diagram, Fig. 2, shows only one regulating resistance, which can be put in either phase. It should always be in the same phase as the shunt circuit, as that is where it gives the maximum regulation of true load. In adjusting this regulating resistance to keep the reading of the standard wattmeter constant as the line voltage varies slight changes in the power-factor are introduced on account of the component in the other phase not being changed in the same proportion at the same time. It is not worth while to attempt to regulate both phases as there is no object in measuring the power-factor with the degree of accuracy required in measuring the true load.

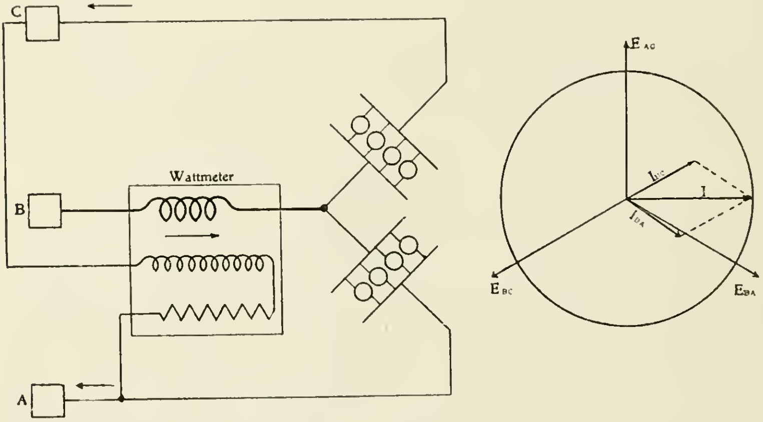

FIG. 4

THREE-PHASE CIRCUIT

With a three-phase circuit the various power-factors are obtained in a similar way. For zero power-factor the load is about equally divided between the two lamp boards and the shunt current is supplied from the outside lines. Fig. 4 shows this connection. E_{AC}, E_{BC} and E_{BA} represent the phase relations of voltages. I_{BC} and I_{BA} are the current vectors for lamp boards BC and BA respectively. Their resultant, I, will be in quadrature with E_{AC} when they are about equal. By increasing one and decreasing the other, the direction of I can be changed to take any position between them, the total angle being about sixty degrees. This corresponds to a range of power-factor from zero to 0.5 both ways or from sixty degrees lead when the load is all on BA to sixty degrees lag when it is all on BC. For power-factors above 0.5 the shunt is plugged on E_{BC}, or E_{AC}. Under the conditions of series current shown in Fig. 4, such a change in phase of shunt voltage would change the power-factor from zero to about 86.6. If the load is all on one lamp board and the shunts are fed from the same phase as the other lamp board, the power-factor is again 0.5, but any combination of currents from the two phases gives a higher power-factor. For example, the shunts may be plugged in E_{BC} while the current is all on lamp board BA. The angle of lag is sixty degrees or the power-factor 0.5. Gradually shifting the load from BA to BC changes the power-factor through successive steps until, when it is all on BC, the power-factor is unity.

The use of the induction regulator in adjusting the phase relation of the shunt and series currents has not been mentioned. It is not an essential part of the equipment, but affords a means of quickly making comparatively small adjustments in phase and voltage of the shunt circuit.

The series auto-transformer and the plug switches in the series circuit also are special. The shunt plug switch is only a slight modification of a standard plug. Instead of the auto-transformer, provision can be made for connecting in a regular series transformer when heavy current is required. These work very well through a low resistance such as the series coils of two or three heavy current wattmeters. The extra line for the shunt circuit is necessary only on special work, where an entirely independent line is required. It can be put to convenient use on tests requiring frequent changes from one fixed voltage to another, by connecting it to give the required ratio to line voltage. Changing the plug from one receptacle to the other is easier than changing the connections to transformer taps each time.

The binding-posts for connections in parallel with the lamp boards are convenient when the load has to be increased beyond that which can be obtained with the lamps, and also for putting in any special load. As the two lamp boards have a permanent common connection on one side, a single wire connected between the opposite sides puts them in parallel. All of the lamps in both lamp boards are then available for single-phase tests, but the outside switches must not both be closed at the same time.

ALTERNATING-CURRENT GENERATORS—II

NOTES ON THEIR CONSTRUCTION, PERFORMANCE AND OPERATION

P. M. LINCOLN

CONSTRUCTION (Continued)

Collectors—The collector rings are built up on a separate spider and bolted to the end of the field hub. The spider hub is faced off for this purpose and lugs left at proper places on the collector so that it may be firmly bolted to the faced-off hub. The collector is of the open type, to secure a maximum ventilation. The rings are usually composed of cast iron. Carbon brushes are used. These, in connection with the cast iron rings, form a combination that has in the past given most excellent results. A typical collector is shown in Fig. 11.

Balance—Electrical balance is secured by making the field run central with the stationary part. If the field is out of center an electrical unbalance must necessarily take place, which manifests itself, depending upon the type of winding in the stationary element, either in a side pull toward the point where the air gap is a minimum, or else in an excess of current in the armature windings on the side which runs nearer the poles. In the latter case there is practically no magnetic side pull. This condition depends upon whether the armature winding is multiple or series. If series, a side pull takes place with the armature out of center, and the shaft should always be designed to be amply strong under a displacement of 0.03 inch.

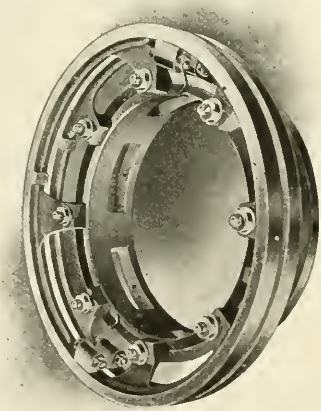

FIG. 11—SPIDER TYPE COLLECTOR

Air Gap—The air gap of alternators is closely related to the performance and other characteristics of the machine. The greater the number of poles, other things being equal, the smaller the air gap. Consequently for slow-speed and high-frequency machines the air gap may become quite small, and on the contrary, for low-frequency, high-speed machines, such as turbo-generators, the air gap becomes very large. The air gap is a function of the number of ampere turns per pole in the armature and the greater the number of poles, other things being equal, the smaller the number of ampere turns per pole and consequently the smaller the air gap.

Slots and Teeth—In the design of slots and teeth there are two opposing requirements. An open slot allows cheapness in manufacture and ease in repair as the coils may be wound on a form and put in the slots complete. The partially closed slot is more difficult and expensive to manufacture but it secures a slightly higher efficiency by preventing the "tufting" of the lines of force.

Fig. 12 illustrates what is meant by the term tufting of lines. When the air gap is small and the width of teeth relatively large, a condition similar to *B* is obtained. Practically all of the magnetic lines issue from the armature at the ends of the teeth. If there is not sufficient room between the ends of the teeth and the pole for these tufts of magnetic lines to unite in a practically continuous belt as in *A*, they will enter the pole face in the tufted condition.

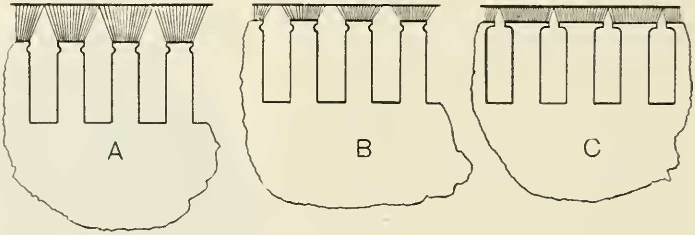

FIG. 12.

If the conditions are as in *B*, there will be a marked difference between the strength of field opposite a tooth and that between teeth. These teeth, moving rapidly across the pole face, produce rapid changes in field strength at the pole face. Since both the hysteresis and eddy current loss in iron increase with the rate of change of magnetic field, it follows that with magnetic condition similar to *B* an undue amount of loss will take place in the pole face. The partially closed slot shown at *C*, avoids the tufting and therefore the undue losses when the air gap is small compared to the width of tooth. With relative dimensions approximately as shown in *A*, the necessity for partially closed slots does not obtain. In the great majority of alternators, however, dimensions are such that the partially closed slot makes a very material decrease in the losses.

Also by the use of partially closed slot, the liability of objectionable noise is greatly decreased.

The use of a partially closed slot necessarily involves the use of either hand winding or a 'shoved-through" type of winding. In the first case the wire for winding the armature coil is pushed through the slot back and forth over properly placed forms until the winding is complete. A partial winding thus made is shown in Fig. 13. The shoved-through type may be again logically divided into bar winding and wire winding. In the bar winding only a single bar is used per slot and each end of this bar is joined to another under an adjacent pole by a properly formed end connector. A well known example of this type of winding may be found in the 5 000 hp generators of the Niagara Falls Power Company. In the wire winding an entire coil is wound up in a properly shaped mould and then cut open at one end. The cut ends are then straightened out and shoved through the proper slots until the coil is in position, after which they are again joined together. The terminals of each coil are, of course, connected to other coils to form a properly

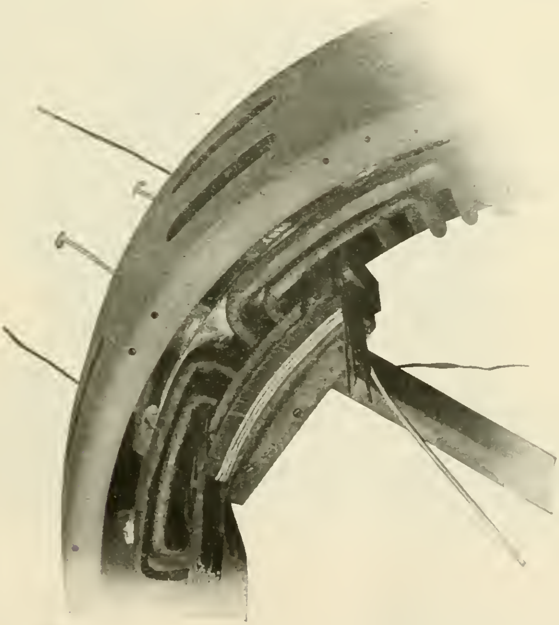

FIG. 13—METHOD OF WINDING HAND-FORMED ARMATURE COILS

grouped winding. Figs. 14 and 15 show a shoved-through type of winding in a partially completed state.

Ventilation—The proper ventilation of any electrical machine is one of the most important elements of its design. In every electrical machine losses necessarily take place. These losses appear as heat. The accumulation of heat raises the temperature, the alternator begins to radiate its heat to the surrounding air. The higher the temperature the faster the radiation, and the temperature keeps on rising until the rate of radiation is equal to the rate of production of heat. The rate of radiation depends on ventilation as well as upon the temperature elevation. It follows, therefore, that with given losses the temperature elevation will be smaller with good ventilation than with poor. In other words, with good ventilation a greater output can be secured with the same materials, the temperature being the same.

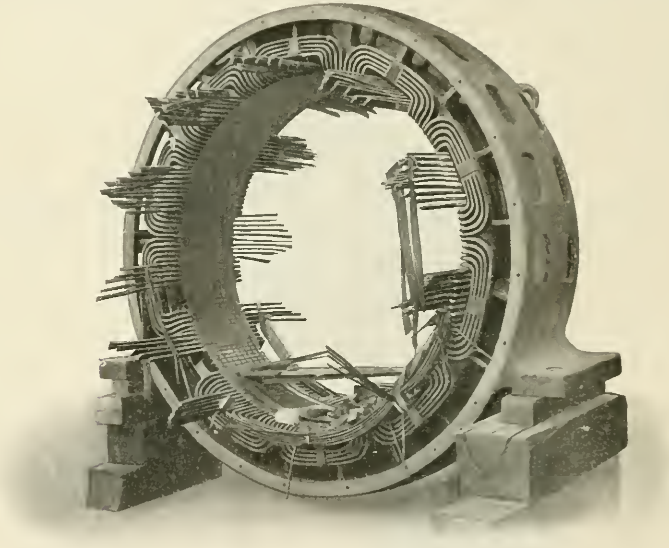

FIG. 14—METHOD OF WINDING SHOVED THROUGH ARMATURE COILS

A method of ventilation often used is shown in Fig. 16. The air is entrapped by ventilating ducts in the revolving parts and is forced outward by centrifugal action. The ducts in the rotating part are made to register as closely as possible with those in the stationary part; consequently, the air from the ducts in the rotating part is forced through them and then through the registering ducts in the stationary element. From the back of these ducts it escapes through openings in the cast iron frame. It is highly important that this matter of ventilation be closely studied and means provided to carry off the heat in the most efficient manner possible.

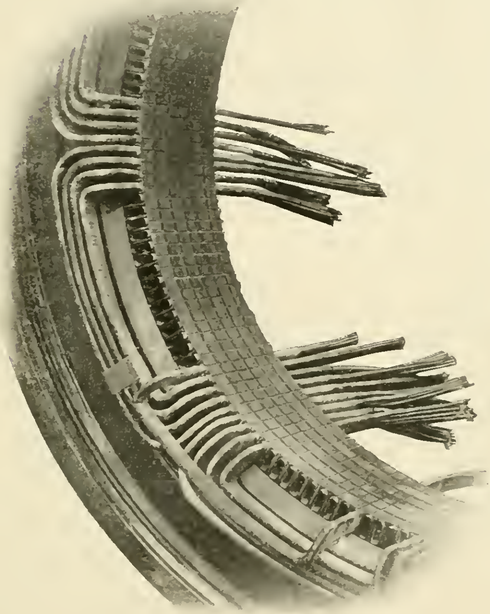

FIG. 15—DETAIL OF ARMATURE BEING WOUND WITH SHOVED THROUGH COILS

Winding—When the first polyphase machines were brought out a winding was used that was practically the same as a winding for a direct-current machine, taps being made at the proper points to secure the phase relations desired. This is illustrated in *A* and *B*, Fig. *A* being the two-phase and *B* the three-phase arrangement. This is the so-called "closed" type of winding. Modern alternators are almost universally of the "open" type winding, diagrammatically illustrated in *C* and *D*, Fig. 17, *C* being the three-phase and *D* the two-phase arrangement. The two-phase open windings are normally insulated from each other within the machine, but may be connected if desired. By connecting the two center points a voltage across the terminals may be obtained, that is 0.7 of that

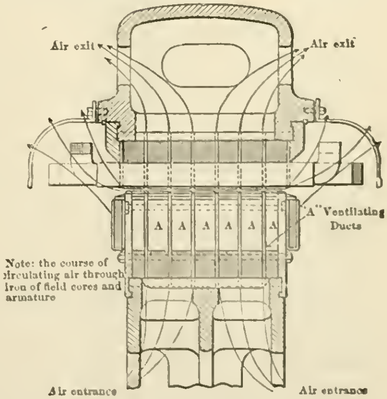
Air exit
Air exit
"A" Ventilating Ducts
A
A
A
A
A
A
Note: the course of circulating air through iron of field cores and armature
Air entrance
Air entrance

FIG. 16—CROSS-SECTION THROUGH FIELD AND ARMATURE, SHOWING VENTILATING DUCTS

across each phase. This is often useful for starting induction motors at a reduced voltage. By connecting the outside ends of the two phases of an open coil winding together a three-wire phase system may be operated.

Voltage—The standard windings of modern alternators are for 220, 440, 1 100, 2 200, 6 600, 11 000 and 13 200 volts. For windings of 6 600 volts and above the questions of insulation and ventilation make it necessary both to increase the length of the machine over that for 2 200 volts and below, and also to decrease the output somewhat, the amount of material on the machine being otherwise equal. Other voltages may be obtained, but they are usually special.

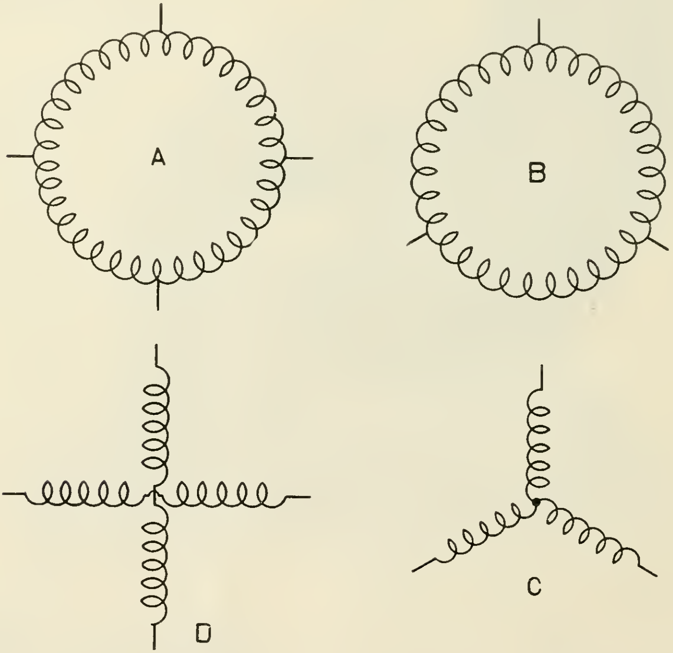

FIG. 17

Phase and Frequency—Standard alternators are made for frequencies of 25 and 60 cycles per second and for single-phase, two-phase or three-phase operation. Other frequencies may be obtained if desired, but such machines must be regarded as special.

Insulation Tests—The test which is most useful and should be most often applied is the measurement of the insulation resistance between the armature winding and the core, and between the field coils and the frame. This resistance measurement will give an indication of the average condition of the insulation as regards moisture and dirt, but will not in general detect weak spots. The higher the resistance the better the general condition of the insulating material. As an approximate figure, one megohm per thousand volts of rated e.m.f. when the machine is warm may be taken as indicating a fairly satisfactory condition of the machine in the armature of the generator. The field will easily have a much higher insulation resistance in proportion to the e.m.f. of the exciting current and will in general give little trouble. It must be remembered that since large armatures have much greater areas of insulation, their insulation resistance will be proportionally lower than that of small machines. Even if the insulating material is in exactly the same condition, the insulation resistance of any machine will be found to be much lower when hot than when cold. The figure of one megohm per thousand volts of rated e.m.f. applies to machines at full-load temperature.

The only feasible way of increasing the insulation resistance when the machine is complete is by "drying out." Armature windings and field coils are dried out by heat. Baking in an oven is to be preferred, but is often impracticable. They are commonly heated by the passage of current through them. The armature may be dried out by short-circuiting the leads and running the generator with a low field charge, just sufficient to produce the proper current. There is always danger of overheating the windings when drying them with current, as the inner parts which cannot quickly dissipate the heat generated in them and which cannot be examined may become dangerously hot, while the more accessible and the more easily cooled portions are still at a comparatively moderate temperature. Several hours or often days may be required to dry out machines, especially thost of large size. Large field coils dry very slowly.

Insulation resistance is conveniently measured by means of a high resistance voltmeter and a direct current. The voltmeter should be connected in series with the insulation resistance to be measured. The insulation resistance $= \mathrm{R} \times \frac{V-e}{e}$, where c, is the observed voltage, V the voltage of the line, and R the resistance of the voltmeter. Another test used to determine the strength of insulation of a machine is made by subjecting the insulating material to an e.m.f. greater than it will have to stand in actual service. The test is of the nature of an over-load and must be applied with great caution. It should discover the presence of any weak spots. These tests are always made in the factory on the completion of other tests and rarely need be repeated. When made away from the factory, it is well to bear in mind that the insulation is more easily broken down when hot than when cold, and that the test should not be made until after the machine has been thoroughly dried out. Tests of this character should not be made when the insulation resistance is low.

Large machines, when tested at high voltage, will require a considerable output from the raising transformer as a charging current flowing to the machine being tested might overheat a small transformer. The transformer capacity required for testing varies as the square of the voltage of the test, as the frequency of the circuit and as the static capacity of the apparatus under test. A 5 kw transformer has sufficient output for testing machines up to 500 kw at a testing voltage of 6 000.

When making a high voltage test the current should be thrown on and off by opening and closing the low tension circuit.

The severity of the test depends in a marked degree upon the time the e.m.f. is applied. A test continued for a minute is much more severe than the same test applied for one or two seconds only. Unless otherwise stated, all break-down tests should be applied only momentarily, as a long continued test is liable to cause permanent injury to the insulation even if no immediate fault is developed.

PERFORMANCE

The performance of alternators will be considered under the following heads: Regulation, Efficiency, Temperature, Capacity, Power-factor and Rating.

Regulation—By the term regulation is usually meant the per cent rise in voltage that will take place when full-load at unity power-factor is thrown off the alternator, the speed and field current remaining constant. Other definitions consider the drop in voltage with load thrown on, field current remaining constant, the increase in field current with load thrown on voltage remaining constant and the decrease in field current with load thrown off, voltage remaining constant, speed always remaining constant. Power-factor is assumed as 100 per cent, or if it is otherwise a specific power-factor is stated. The first definition is the one assumed unless otherwise stated. The regulation of the e. m. f. of an alternator is an important element for a satisfactory service. Efficiency affects the cost of power; temperature affects the life of a machine; speed and frequency are determined once for all and affect the engineering of a plant; but regulation affects the customer.

The e. m. f. of a generator depends upon the speed and upon the field current, but even when these are constant there is a decrease in e. m. f. as a generator is loaded, due to three causes,—the resistance of the armature windings, the self-induction of the armature, and the demagnetizing effect of the current in the armature windings. In well designed machines the resistance has a negligible effect, the self-induction is of small consequence and the demagnetizing effect is the principal cause of drop in e. m. f.

Self-Induction—The coils in an armature act as a choke coil in lowering the e. m. f. when current flows through them. The self-induction depends upon the number of turns of wire and upon the arrangement or distribution of these turns. If the turns are placed in coils of, say ten turns per coil, then the magnetic lines which are set up by the current in each turn tend to pass through all ten turns. If the ten turns be separated and placed in separate slots, then the magnetic field set up by the current in each turn passes almost entirely through that turn alone and has little effect upon the other turns. The choking effect resulting from the self-induction depends upon the magnetic flux through the turns, and is therefore much less when the turns are separate than when they are combined into coils having a larger number of turns. This is one reason that alternating-current generators are wound with as many slots as practicable. The old toothed armature machines had but one slot per field pole and the regulation was comparatively poor.

The self-induction in an armature produces a greater drop the greater the lagging of the current; i. e., the lower the power-factor of the load.

Demagnetizing Effect—The e. m. f. induced in an armature coil depends upon the actual magnetic flux through the coil. This magnetic flux is produced mainly by the field current, but partly by the armature current. If the field current be constant, then the resulting magnetization and consequently the e. m. f. will depend upon the effect of the armature current. The latter effect will increase as the current increases, and depends also upon the position of the armature coils at the time when the maximum current flows. The individual coils on an armature are connected into groups, equal in number to the number of field poles. When a current passes through the armature winding, the current in each group of coils flows around a common center and produces a magnetization which is alternately positive and negative in the consecutive group of coils. If the time of maximum flow of the alternating current occurs when the armature coils (i. e., groups of coils) are midway between the field poles, then the magnetic lines extend out into space between the fields and neither increase nor decrease the magnetization from the fields. If the maximum current flows when the armature coils are directly in front of a field pole, the magnetization will be increased if the direction of the armature current is the same as that of the field current, and vice versa. It is evident, therefore, that a current in phase with the e. m. f. has little effect in reaction upon the field, but that a current which lags or leads 90 degrees is in the position to give a maximum effect in decreasing or increasing the magnetization and the e. m. f. of the machine. A current which lags less than 90 degrees can be resolved into two currents, i. e., is equivalent to two currents, one of which is in phase with the e. m. f. and the other at right angles to it. The regulation of the generator is therefore determined in a very large degree by the lagging component of the current. A leading current may be considered in the same way, the regulation of the machine depending almost entirely upon the leading component of the actual current.

There is a direct relation between the power-factor of the load (or the ratio between the apparent output of a machine and the true output in power) and the lagging of the current behind the e. m. f. The relations between the power-factor, the lag of current behind e. m. f. and the demagnetizing effect of the armature current upon the field (presuming it to have a maximum of 100) are:

Power-Factor	Lag	Demagnetizing Effect
0 per cent.	90 degrees	100
71 per cent.	45 degrees	71
80 per cent.	37 degrees	60
85 per cent.	32 degrees	53
90 per cent.	25 degrees	44
95 per cent.	18 degrees	31
100 per cent.	0 degrees	0

It will be seen that a power-factor of 95 per cent causes a demagnetizing effect equal to about one-third of the maximum which is possible.

When a machine delivers lagging current the demagnetizing effect of the armature current must be counter-balanced by increasing the current through the field if the e. m. f. is to be held constant. This may be done by hand, by a compensating winding or by an automatic regulator, such as the Tirrill regulator.

Polyphase and Single-Phase Alternators—For a given regulation the capacity of an alternator operated single-phase is less than its capacity operated polyphase in approximately the ratio of seven to ten. This statement is general and applies to three-phase as well as two-phase alternators. Further, this difference is one which is inherent. The impression exists that a given size of alternator can be designed for as large an output single-phase as polyphase. This is not true. For a given regulation the output that can be obtained from a given size of single-phase alternator is only about seven-tenths of that which can be obtained from the same size of polyphase alternator. For a given regulation therefore, the weight of a single-phase alternator is 40 to 50 per cent greater than that of a two or three-phase alternator of the same capacity.

(To be continued.)

EUROPEAN GAS ENGINE PRACTICE*

RUDOLPH WINTZER

DURING the last five years several large central stations have been established in Europe using producer gas engines. The largest power plant using producer-gas is located in Madrid, Spain, furnishing light and power to the entire community. It is equipped with six 1 250 kw (2 000 hp) Nurnburg gas engine alternators operating in parallel, supplied by a Mond producer gas system using low-grade slack coal. The gas-engine is used to a very great extent with suction producers, in water pumping stations for small cities and counties, especially in Western Germany. "Braunkohle" (corresponding to our peat) and lignite in the form of briquettes is largely used in these small plants and with excellent results.

The greatest development of the gas engine on the continent has taken place in connection with blast furnaces and the coaling industry where the waste gas from furnaces and coke ovens are largely used for power. A large enterprise of this character is now being carried out near Essen in Rheinland. Essen is the Pittsburgh of Germany. Within a radius of forty miles occur most of the largest coal mines and iron and steel works of that country. Most of the existing central stations in the district have been acquired by the steel syndicate, which is erecting large central stations driven by blast-furnace and coke-oven gas to furnish this whole industrial section with electricity for lighting, power and traction. Some customers in the territory have requisitioned as high as several thousand horse power. These central stations will be erected at the various steel mills and mines, and will all work in parallel.

Typical gas power stations using blast-furnace gas, are now working at the following plants: John Cockerill Company, Seriang, Belgium, 3 000 kw; United Iron and Steel Works at Hoerder, Westfalia, 3 500 kw; Schalker Iron and Steel Works, Gelsenkirehen, 4 000 kw; Rompacher Iron Works, 3 000 kw. A typical plant driven by coke-oven gas is located at Eschweiler mines at Alsdorf, where a central station of 2 800 kw is in service, using Otto coke ovens with recovery of by-products. This plant furnishes current for driving 3 000 hp main hoisting engines, pumps, fans, compressers, coal-washing plants, etc., and for electric traction service in the neighborhood. No steam is used in these works, and a producer plant is available as a reserve in case of necessary shutting down of the coke ovens. In a short time this plant will work in parallel through a long high-tension transmission with an hydraulic plant forty or fifty miles distant, installed by the Ruhr River Hydraulic Development Company.

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* From Proc. A. I. E. E. Pittsburg Branch Meeting.

While formerly the practice was to drive large rolling mills directly with large gas engines, the present practice is rapidly tending to motor-driven rolls, supplied with power from a central station.

At Differdingen, in the steel and coal works of the Germany and Luxemburgh Steel & Mining Company, it has been found by careful experiments that for every 1 000 hp maximum required at the main rolling-mill with engine-driven rolls, only 600 hp capacity is required at a central station. A number of units are provided, giving flexibility of service, and forty per cent is made on the first cost of the gas-engines installed.

TYPES OF GAS ENGINES IN USE

For large work three types are represented, namely:

1—The four-cycle, double-acting tandem engines of Nurnburg, Deutz and Cockerill.

2—The two-cycle, double-acting Koerting type.

3—The two-cycle, double-acting opposed, Oechelhauser engine.

Of these three types, the four-cycle type has become standardized for general power station work, while the two-cycle types have found their most extensive application to blast furnace work. Four-cycle tandem engines are operating up to 2 000 hp; that is, 1 000 hp per cylinder. Two-cycle engines have also been built from 750 to 1 000 hp per cylinder. Comparing the constructions of the three types for 1 000 kw units, it is found that the four-cycle engine has one connecting-rod and two power cylinders; the Koerting engine has two connecting-rods, two power cylinders, four compressor sylinders of nearly the same diameter and two side connecting-rods; the Oechelhauser two-cycle engine has a six-throw crank-shaft, four bearings, six connecting rods, four single-acting pistons and two compressor cylinders. In the Koerting engine the exhaust ports in the cylinder wall are uncovered by the piston; in the Oechelhauser engine the pistons uncover both exhaust and air ports so that no valves are used. This elimination of valves in the Oechelhauser and Koerting types looks at first sight like a simplification, but in reality it involves serious complications in the number and disposition of the principal working parts.

European practice has definitely tended toward the single-crank units, and the horizontal tandem, double-acting type has become the standard in this respect. By duplicating the tandem arrangement, making a two-crank engine, the economy is not improved and the speed variation of the single-crank type is found to be close enough for alternating-current work. The single-crank units give far greater flexibility in central station operation; they can be loaded more economically, and there is more opportunity for inspection and repairs. The sizes mose frequently used are 1 000, 1 500 and 2 000 hp.

ELECTRICAL OPERATION

In regard to the electrical specifications for gas-engine work, Continental firms usually specify a cyclical fly-wheel deviation of $\frac{1}{40}$ to $\frac{1}{60}$ the pole distance in engines with one impulse per stroke. This condition can easily be met and takes into consideration occasional irregular working. In a 500 hy engine, of the vertica double-acting type driving spinning machinery at the Hollins Mills, Marple, a cyclical speed variation of 0.2 to 0.4 per cent was obtained, which was increased to only one per cent when one cylinder was made to misfire regularly. The cyclic speed variation was taken with a very sensitive and well made recording tachometer. It is a matter of interest that the steam-engine, which formerly did the work of this gas engine, showed eight per cent cyclic variation, and it is not surprising therefore that the mill tenders had less trouble from broken threads after the gas-engine was put in service. Troubles from parallel operation are practically unknown in engines above 1 000 hp giving two impulses per revolution and 25 cycles.

A type of alternator in general favor is a combined fly-wheel and generator field in one structure, with the fly-wheel rim outside the rotating field. With the usual speed of periphery of field, this permits a high fly-wheel speed with a short distance between the bearings and good accessibility.

FUELS

In Germany, the cost of hard coal is $5.50 to $6.50 per metric ton (2 220 pounds), according to facilities of transportation. Good bituminous coal costs $3.50 to $5.50 per ton delivered at the plant. On a small scale, anthracite is largely used, but in very large plants, such as that of Madrid, low-grade bituminous coal is mostly used. The Mond Producer system has greatly enlarged the possibilities of low-grade bituminous fuels.

ECONOMY

With blast-furnace gas the 1 000 hp engines at Rombach and Ruhrort have shown a heat consumption as low as 9 300 b.t.u. per brake horse power hour at full-load, and 12 000 at half-load, using the lower or effective heat value of the gas. High-grade Mond gas-plants in England have shown economies of 1.1 to 1.2 pounds of slack coal per brake horse power hour, including all standby losses for the balance of a 10-hour working day. In this particular the producer has a very large advantage over steam, and especially superheated steam plants, as the standby losses are almost negligible. At a large European iron and steel works at Essen, extensive tests were made to ascertain the standby losses on the steam-piping system which was in fair condition and completely lagged. With no steam used for driving engines it was found necessary, in order to maintain normal pressure, to keep twenty 180 hp boilers under full fire.

In well constructed horizontal gas engine plants the oil consumption is no higher than in a corresponding steam engine plant. For instance, a 1 000 hp tandem gas engine requires on an average of 35 to 40 lb. of oil (4.75 to 5.25 U. S. gal.) per 24 hours, 60 per cent being cylinder oil at 35 cents per gallon, 40 per cent being engine oil at 20 cents per gallon.

COST OF EUROPEAN PLANT

For a 2 000 hp high-grade gas engine plant the distribution of cost should be about as follows:

	Dollars per brake horse power
Gas engines	$30.00
Foundations	2.20
Auxiliaries	0.80
Building	4.00
Piping and engine outfit	3.00
Electrical outfit	14.00
Gas producer plant	14.00
Producer house	1.50
Total	$69.50

or very nearly $100 per kilowatt. About a year ago high-grade gas engines sold for about $25 per brake horse power. The present prices are somewhat higher. For high-grade steam engines using superheated steam the cost is about the same, $25 per brake horse power.

A PECULIAR STATIC TROUBLE

R. P. JACKSON

A FEW cases have been noticed recently where static disturbances having no connection with lightning have caused trouble and damage. A typical instance was that of two 6 600 volt generators delivering power to a transmission line through delta-connected transformers having a ratio of 6 600 to 66 000. It was found that when a ground occurred on one leg of the transmission line static disturbances and breakdown of the insulation occurred on the generators. The probable key to the cause of this action is furnished by an investigation of the static conditions prevailing in the circuit.

The two windings of a transformer act as the two plates of a condenser. This will be readily appreciated if it is remembered that when a single terminal of a transformer is connected to a high-tension circuit, the other terminal being idle, there appears a difference of potential between the second coil of the transformer and the earth. This is due to the fact that one winding of the transformer by being connected to the high-tension circuit has its potential rapidly changed from positive to negative. Consequently, the other coil of the transformer, which acts as the second plate of the condenser, has induced upon it a charge alternately positive and negative, which may give a spark to ground.

If the one coil of a transformer has its two ends connected to the two wires of a high-tension circuit, then the average potential of the primary winding will be the mean of the potential of its two terminals. If these two terminals are alternately positive and negative and these potentials are symmetrical with respect to the earth and if the positive value of the one is equal to the negative value of the other, then the potential of the coil is zero, and consequently no charge appears upon the second coil, provided the windings are symmetrically related. If, however, one terminal of the circuit be grounded, then the average potential of the primary is equal to half the voltage of the circuit and a charge will appear upon the secondary winding. If the secondary winding of the transformer is connected to an insulated circuit, such, for example, as the armature of a generator, then this whole circuit will be subject to an alternating static charge, provided one terminal of the high-tension winding is grounded. The potential difference between this circuit and the ground will depend upon the numerical relation of the capacity between the high-tension and the low-tension windings of the transformer to the capacity between the insulated circuit, including the high-tension windings, the generator armature and the earth.

In the case of a three-phase circuit the same general principles apply with some modifications. Three delta-connected transformers well insulated from ground may be represented by a triangle rotating about its center as shown in Fig. 1. The horizontal line represents zero or ground potential. Thus, part of the transformer windings will be seen to be charged to a positive potential and part to a negative. The numerical value of the potential at any point is proportional to the distance of that point from the neutral line at that particuler instant. As charges are proportional to the product of static capacity and potential it will be found by multiplying each element of the windings by its distance from the neutral line and adding the products that the negative and positive charges are always equal. As the phases of the three transformers change the triangle rotates but the charges remain fixed in relation to the neutral line, with the result that the two charges actually follow each other around the delta in a manner similar to the north and south poles of an induction motor due to its rotating magnetic field. As in this case the two charges are always equal no current has to be supplied from ground

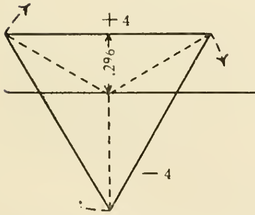

FIG. 1

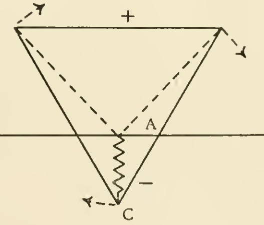

FIG. 2

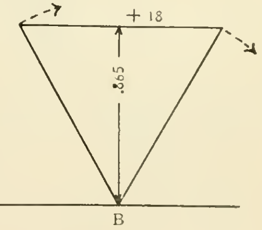

FIG. 3

This is not the case when a point in the delta becomes partially grounded as, for example, through a very high resistance. The condition is now shown by Fig. 2. The triangle still rotates but the center of rotation is displaced toward the point in the windings at which the partial ground exists. The positive and negative charges on the windings are no longer equal, however, as at times there is more positive and a little later in the cycle the negative charge is the greater. The result is that an alternating charging current has to be supplied through the partially grounded point.

If one leg of the transmission line becomes solidly grounded, the condition shown in Fig. 3 exists in which the triangle is rotating around one corner. In this case all the windings become alternately positive and negative in relation to the ground and if each element of the triangle is multiplied by its average distance from the neutral line and the products added as before the charge will be found to be 4.5 times as great as each of the charges on an ungrounded system. All of this current has to be supplied through the grounded point.

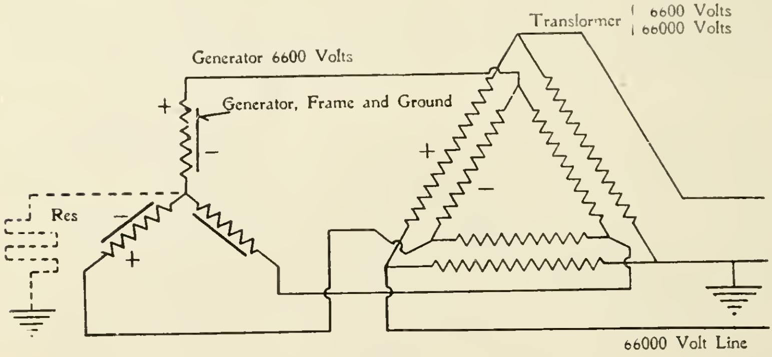

FIG. 4

Figure 4 shows how this condition may cause trouble. The high tension windings of the delta receive alternately positive and negative charges and with the low-tension windings form a condenser. The generator forms, likewise, a condenser between its windings and the iron. These two condensers are in series between the high tension windings and ground. Two condensers in series divide their potential strains inversely as their capacities and as the capacity of the generator windings to the iron is generally large the corresponding strain on the insulation may not be great enough to puncture it. In the case mentioned, however, one generator was feeding a bank of large transformers and the capacity of the high and low tension windings to each other was comparable to that of the generator windings to ground. Of the 66 000 volts across the two condensers somewhere near half could be across that formed by the generator windings and its iron. Any voltage near 30 000 volts is obviously a destructive potential for apparatus insulated for 6 000 volts and the result would be a puncture.

A step down transformer on a transmission line will be subject to strains to its iron and case but if oil insulated it is usually better able to withstand them than a generator. The obvious remedy is to ground some point, preferably the neutral, of the low tension windings as indicated by the dotted lines in Fig. 4, so that the charging current can be supplied directly. It is not necessary that this ground should be a complete one but only that a sufficiently low resistance be inserted between some point of the windings and the ground to permit the charging current to flow without a large rise of potential.

When obscure cases of insulation break downs occur, it is well to look for possible causes analogous to the one here described.

60 000 VOLT SERIES TRANSFORMERS

W. H. THOMPSON

THE series transformer for use in connection with measuring instruments is usually a very insignificant looking piece of apparatus. The output is small and the windings are simple. If, however, the transformer is to be used on a high pressure circuit, the insulation requirements lead to some rather remarkable proportions.

In Fig. 1 is shown one of a number of series transformers recently built for use on 60 000-volt circuits. The total height of the one shown, including the terminal, is eight feet, and its capacity is 40 watts. The ratio is 200 amperes primary and five amperes secondary. These transformers are insulated to withstand a breakdown test of 120 000 volts for one minute.

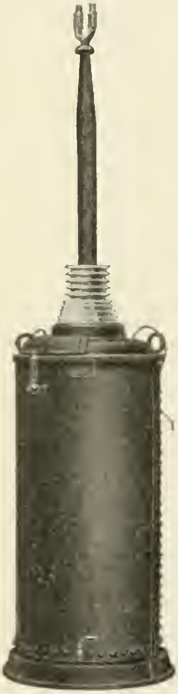

FIG. 1—60 000 VOLT SERIES TRANSFORMER

The diagram, Fig. 2, shows the method of connecting to the high voltage line. A small spark gap is connected between the primary terminals to act as a protection to the primary line in case line surges should occur, which might injure the internal insulation of the primary coil. Under normal full-load conditions the drop between the primary terminals is very small, and hence there is no necessity for much insulation. They, therefore, are brought out through the same insulating tube and bushing. As may be seen in Fig. 1 the high tension bushing is of extraordinary length. This is necessary in order to provide surface between the terminals and the cast iron cover of the case. The bushing extends down inside the case about the same distance as outside. The transformers are oil cooled and hold about 52 gallons of oil. The transformer itself, without oil, weighs 275 pounds.

In some cases it is desirable to operate both meters and circuit-breaker from this type of transformer. In such cases a transformer with separate secondaries is provided, as shown in Fig. 3. This is done because the variable load of the circuit-breaker affects the ratio of the transformer if there is only one magnetic circuit. Transformers of this type with two secondaries have been constructed for the Niagara, Lockport & Ontario Power Company. They are similar in appearance to the one shown in Fig. 1, except that the case is taller and four secondary leads are brought out. These transformers are provided with one primary on which are mounted two separate magnetic circuits, one for each secondary. This arrangement makes the two secondaries entirely independent.

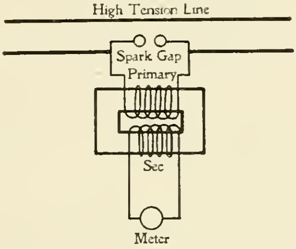

FIG. 2

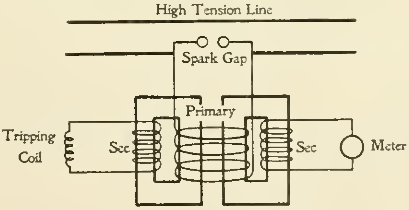

FIG. 3

MECHANICAL SYNCHRONIZING

H. S. BAKER

SOME TIME ago a detailed description of an automatic synchronizer was published in the JOURNAL.*

One of these instruments is now in operation in connection with the rotary converter station of the Syracuse Rapid Transit Company, of Syracuse, New York. The load on this station, being entirely a street car load, is extremely variable and the synchronizing of the rotary converters by hand was a difficult and a tedious matter, often taking ten or fifteen minutes to get the machines parallel and switched in on the alternating-current side. The synchronizing is now turned over to a simple piece of apparatus that can be said to know accurately the difference of frequencies of the incoming rotary converter and the bus-bars and also exactly when synchronism occurs, whereas the operator who had previously done the same work had to depend on his judgment and skill. This instrument is provided with adjustments whereby the maximum difference of frequency at which the main switch will be closed, may be varied. The length of time before synchronism at which it is necessary for the instrument contacts to close in order that the main switch will be closed exactly at synchronism may be varied to suit the time element of the particular switch use. One synchronizer is provided for a number of machines, but a separate control switch is ordinarily provided for each machine.

The accuracy of operation of this automatic synchronizer is such that the converter can safely be connected to the bus-bars while there is still such a difference of frequencies that it would be dangerous to attempt hand closing of the alternating-current switches. Also there are no possible safe chances to close the alternating-current switches which are lost, due to indecision or lack of nerve, because the synchronizer has neither of these. In actual operation with the synchronizer, the time taken from stand still to the closing of the main switches, under these extremely variable conditions, is from one-half to two minutes, including the time required for the starting motor to come to speed instead of the much longer time which was often required when the voltage was fluctuating over a wide range. It is a pleasure to watch this little device do with precision what has heretofore been done by guess.

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*See *The Electric Journal,* Vol. II., May, 1905, p. 294.

TESTING LARGE MOTORS, GENERATORS AND MOTOR-GENERATOR SETS—III

INDUCTION REGULATORS

C. J. FAY

INDUCTION regulators are so similar in their electrical design to induction motors that they are included under the above heading. As nearly all large induction regulators are air-cooled and most of them are six-phase double delta-connected, this is the type that will be considered. The tests given other types differ only in a few minor details. The six-phase regulators are usually intended to regulate the voltage for six-phase rotary converters and in testing a regulator of this type it is connected up to the converter with which it is to run or with one of the same kind. The converter is run inverted, direct current being supplied at a voltage such as to giving the required alternating-current six-phase voltage on the regulator primary. In preparing for a test the regulator is placed near the converter and connected up to it. A motor-operated fan is connected by a large pipe to a draft box upon which the regulator is placed. This draft box is constructed so that the air entering from the fan is forced up through the regulator and out at its top.

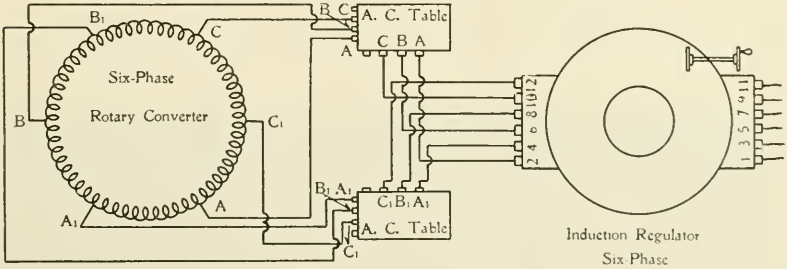

FIG. 1

The first test, as in nearly all machines, is the measurement of the resistance of both the primary and secondary windings. After this has been done the regulator is connected up to the rotary converter through two alternating-current testing tables as shown in Fig. 1. The three leads of one delta are connected through one table and the other three leads through the second table. A known balanced voltage is then applied from the converter and all of the voltage combinations possible in the regulator are tested out to see that the windings are correctly connected and that the circuits are balanced. The rotating element of the regulator is usually placed at the position of maximum boost during this test. In Fig. 2 and Table I are shown the scheme of connections and the readings taken on a six-phase 165 to 16 volt double delta-connected regulator. The secondaries in Fig. 2 are shown at the position of maximum boost.

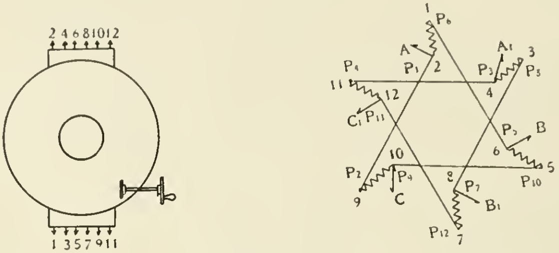

FIG. 2

TABLE I

E. m. f. applied between { 4—8, 4—12, 8—12 / 2—6, 6—10, 2—10 } 165 volts.

Resultant e. m. f. between

Maximum.		Minimum.	Maximum.	
1— 9	194 volts	140.5 volts	1— 2	17.5 volts
1— 5	194 “	142.5	3— 4	17.4 “
5— 9	194 “	140.5 “	5— 6	17.6 “
3— 7	194 “	142.5 “	7— 8	17.6 “
3—11	194 “	142.5 “	9—10	17.8 “
7—11	194 “	141.5 “	11—12	17.7 “
2— 5	174 “		1— 3	113.2 “
6— 9	175 “		3— 5	113.2 “
10— 1	176 “		5— 7	113.2 “
4— 7	175 “		7— 9	112.2 “
8—11	175 “		9—11	113.2 “
12— 3	175 “		1—11	113.2 “
1— 7	226.4 “			
3— 9	226.4 “			
5—11	226.4 “			

Readings for iron loss and saturation curves are taken, at several different voltages, of watts and amperes in each of the two three-phase circuits with the rotating element still in the position of maximum boost. The results obtained from the two circuits are added together and plotted in the form of curves, volts being taken as abscissae and watts and amperes as ordinates.

Next the rotating part is moved to the position of minimum boost and the voltages measured across the secondaries. Readings are also taken at full voltage of the iron loss and saturation in this position.

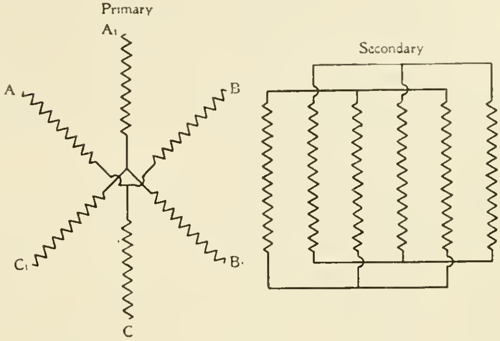

FIG. 3

The heat run is made with full-load current in the secondary. The primary circuits are connected in double star and the secondary circuits are short-circuited on each other in two sets of three circuits per set, as shown in Fig. 3. With this combination the current re-

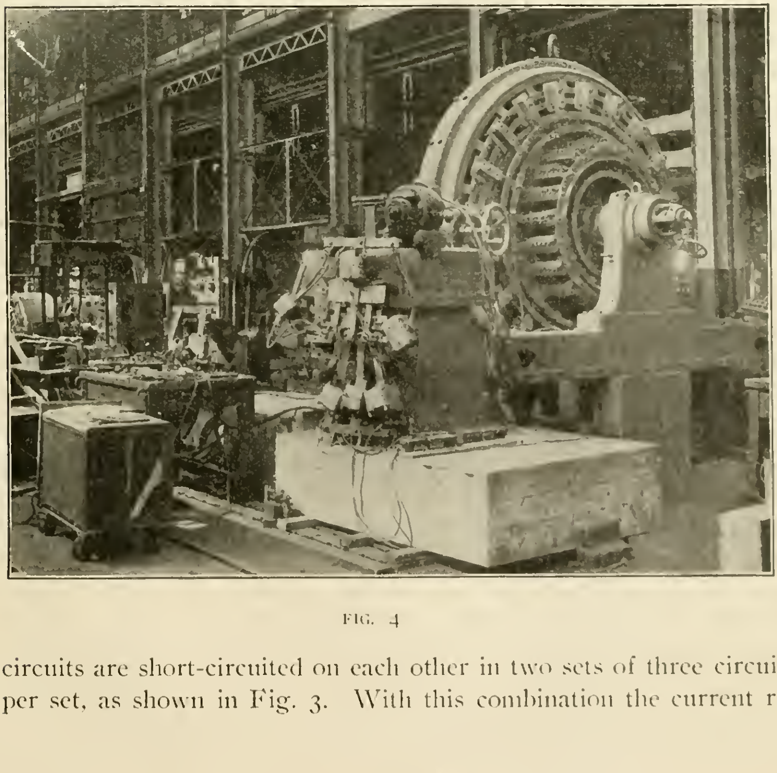

FIG. 4

quired in the primary to give full-load current in the secondary is more nearly equal to the full-load current under normal conditions than with the primaries in double delta. A general view of an induction regulator under test is shown in Fig. 4. This shows the six series transformers connected in the secondary circuits for measuring the secondary currents. The meter leads from these transformers are all brought to a plug board (shown on the draft box) so that one meter may be used and changed from one circuit to another by merely plugging in the desired circuit.

The quantity of air forced through the regulator is measured by passing the air through an opening in a diaphragm in the draft box and measuring the pressure on each side of the diaphragm by the use of a U-tube. Then if A is the area in square feet of the opening in the diaphragm and d is the difference in pressure in inches of water on the two sides of the diaphragm the quantity of air in cubic feet passing through the opening is equal to $2\,400\ A\ \sqrt{d}$. In commercial testing the amount of air pressure to use is usually known from previous tests and the test conducted with this assumed pressure and the amount of temperature rise noted. This will usually be a normal one. On new types or sizes of machines the air pressure is assumed and then if the heating is higher or lower than deemed advisable the air pressure is changed until a suitable rise is obtained.

The rotating elements are usually operated by small motors mounted on the tops of the regulators. These are given a short test in addition to their tests as motors in order to see that they will move the secondaries over their area of travel satisfactorily.

THE VALLEJO, BENICIA & NAPA VALLEY RAILWAY

GEORGE T. HEDRICK

THE Vallejo, Benicia & Napa Valley Railway is the pioneer single-phase road of the West, having been in successful operation between Napa and Vallejo since July 4th, 1905. The town of Napa, where the power house and car barns are located, is forty-eight miles from San Francisco, and is beautifully situated in one of the finest and most fertile valleys in California. The railway runs through this valley, tapping the agricultural and industrial towns along the line, the southern terminus being the town of Vallejo, where steamer connections are made with San Francisco, and where is located the Mare Island Navy Yard. The northern survey has reached St. Helena, eighteen miles north of Napa. This portion of the road will be rapidly constructed as fast as material can be procured. Along the northern end there are numerous summer resorts and mineral springs, and the vineyards are not excelled in all California.

The power for this road is furnished by the Bay Counties Power Company over the longest transmission line in the world, and is changed from 60 to 25 cycle current by two motor-generator sets, each unit consisting of a 585 hp, three-phase, 2 200 volt, 60-cycle induction motor direct-connected to a 400 kw two-phase, 25-cycle 6 600 volt generator of the revolving field type.

The cars are all equipped with multiple-unit control. There are three quadruple equipments with 100 hp motors, and two quadruple equipments with 75 hp motors. At first the road was operated with a trolley voltage of 750, one phase only of each unit being used. There were five 200 kw transformers, distributed along the line at intervals of about three miles, for supplying current to the trolley system which was at that time of standard direct-current construction. This was changed to single-phase catenary construction and the trolley voltage raised to 3 300 without interrupting the schedule of the road in any way. The bracket arms were changed and messenger cables strung with the working voltage on the wire and also a section breaker put in midway on the line, so as to have the line in two sections.

In order to change the system from 750 to 3 300 volts, it was necessary to cut out the 5-200 kw transformers on the line and put in 2-500 kw auto-transformers. For the car equipment it was necessary to take off the main fuse boxes and take out the main trolley cables, and replace with suitable fuse boxes and special insulated trolley cables. To simplify the work as much as possible for the night of changing over, as the time was limited from 12 midnight to 5:30 A. M., the two 500 kw transformers were placed in their permanent position without oil, as the oil to be used was in the transformers that were in service. On the cars the 750 volt main fuse boxes were taken off and the main trolley cables taken out and the 3 300 volt main fuse boxes put on and special insulated main trolley cables put in permanently, but not connected to the trolley bases. The 750 volt fuse boxes and trolley cables were then put up temporarily, so that when the time came to make the change all that was necessary to do was to take the fuses out of the 750 volt lines and put the fuses in the 3 300 trolley line and connect the trolley bases.

On the night that the change over was made, after the day's service was completed, a car was sent out of Napa over the line with three linemen with instructions to cut out the 200 kw transformers as they went along, to cut out the jumper that was on the section breaker, and take enough oil out of the 200 kw transformers for the 500 kw transformer at Vallejo. They were then to telephone to the power station when they were ready to have the power shut off. After receiving word that the power was off they were to connect up the 500 kw transformer to the line, change the car fuses and connect the trolley cables to the bases. Then they were to telephone to the power station when ready to have the power turned on. In the meantime the men at the power station put oil in the 500 kw transformer located in the power station, and made all necessary changes to the switch board and cars in the barn. When word was received from the Vallejo end that they were all ready the power was turned on and everything was ready for service in time to operate the regular schedule with 3 300 volt power.

EXPERIENCE ON THE ROAD

A ROCKY MOUNTAIN TRANSPORTATION

J. E. JOHNSTON

THE generators in this case were two 500 kw machines for direct connection to water wheels at 220 r.p.m. They were delivered at the railway station nearest to their destination and for the remainder of the distance, 17 miles, had to be handled by wagon. A portion of this distance was through level country and a portion through mountains. On the Pacific slope there is a rainy season when roads are almost impassable and in the valleys the bottom literally falls out. It was our luck to have the generator arrive in the rainy season. The revolving field on its shaft weighed nine tons and was the heaviest piece. Under ordinary circumstances this could have been moved easily. The contract for the hauling was given to a "big Swede," who was an artist in his line, but when his loaded wagon struck the soft mud of the "bottomless" road, one side of the wagon began to settle and the field was gently deposited in the mud without material damage.

Our contract did not include the hauling, so the water wheel man, who had finished his job as far as possible, volunteered to go back and reload the field so that the center of gravity would be considerably lower than it was in the first loading. This he did very successfully and left the wagon on planks out of the mud. Then all hands knocked off to wait for a freeze, which occurred in about a week. During this freeze the field was finally brought over the mountain roads to the power house with a 20-horse team. Around some of the short curves it was frequently necessary to have a part of the teams pulling at right angles to the others in order to get the resultant pull in the right direction. The last incident of the haul was the crossing of the river near the power plant. The river was between three and four feet deep at the ford and running with ice. The field was loaded so low that in crossing the river it was partly submerged and water dripped from the windings for several days after it was in the power house, where the accumulated ice could melt. When the machine was started some time later it was found that no harm had come of the wettings which the windings received.

The second generator, which had been left at the railway station, was loaded in February and taken some five miles, when it was decided to give up attempting to haul it until spring. So a shed was built to protect the machine and it was left standing on the wagon. When the roads became good enough for travel the river was too high to ford and we had to wait until low water came in July, when the generator was finally landed at the power house, and the writer finished the installation without further trouble.

BOOK REVIEW

Elements of Electrical Engineering, Vol. I. W. S. Franklin and William Esty; 255 illustrations; 517 pages. Published by the MacMillan Company, New York. Price, $4.50.

This book, just recently from the press, is intended for use as a text book by electrical engineering students. This first volume takes up direct-current machinery, electric distribution and lighting, while the second will treat of the subjects of alternating-current machinery and distribution. The authors of this book are the instructors in Physics and Electrical Engineering at Lehigh University and have been teaching these subjects for some fourteen years. This fact may account for a noticeable feature of this book which is the smoothness and completeness of the demonstrations, beginning with the fundamental physical conceptions and continuing in a simple and direct style and finally bringing the discussion to the practical application in everyday engineering practice. Very often the subjects of Physics and Direct-Current Machinery are taught from different text books in separate classes and sometimes in different years, so that it is difficult for students to get an adequate idea of the close relation of the two subjects. This combination, together with a concise, direct style of writing, have resulted in a book that is an admirable introduction to the more advanced study of electrical engineering. The subject matter has been so arranged by the use of a series of appendices, that the book may be used as an introductory course for those desiring only a general knowledge of the subject as well as for students specializing in electrical engineering.

The first two chapters are taken up with a discussion of the theory of electricity and magnetism, followed by chapters on the operation of the dynamo as a generator and as a motor. A good-sized chapter is devoted to ratings and guarantees in which the recommendations of the A. I. E. E. on this subject are outlined. Two subjects which are not often given adequate attention in many books are here treated in two chapters on Storage Batteries and Photometry.

Perhaps the best example of the simplicity and directness of style characteristic of this book is found in the first part of this chapter on photometry. In a chapter on wiring and distribution the authors have omitted the usual discussion of things which are more or less familiar to everyone, such as the details of construction involved in wiring and have given a full consideration of the bases of wiring calculations.

An important feature of the book is a series of some 235 problems in the last appendix, which are so arranged that they can be used by students without instructors as well as for class-room work.

The appreciation of this book by instructors is shown by the fact that it has already been adopted as a text book by between fifty and sixty technical schools.

A. H. M.

THE
ELECTRIC JOURNAL

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Empirical Tests

In the manufacture of machinery of all kinds the manufacturer naturally wishes to make some kind of a test upon the apparatus to determine as near as possible its ability to fulfill the conditions that it was designed to fulfill. Usually it is impossible to exactly duplicate service conditions on the testing floor, and hence it is necessary to subject the apparatus to some empirical test, which is equivalent to service conditions or as nearly so as it is practicable to secure. In the manufacture of electrical machinery certain tests have been established by custom, in nearly all lines, to determine the sufficiency of the apparatus. In a great many cases the purchaser accepts or rejects the apparatus on the basis of these established tests.

In nearly all of these tests some function of the apparatus is very indefinitely determined. For instance, in running a railway motor on the usual basis of a one-hour test, the ability of the motor to stand overloads is very indefinitely determined. Likewise testing control apparatus by passing current through its various circuits for a certain time very indefinitely determines its ability to successfully manipulate the circuits of motors having the same current carrying capacity. This is due to the heating effect of rupturing the arcs formed in breaking the various circuits to the motors as well as the troubles sometimes experienced from the gases and vapors so formed.

In testing motors and generators, which are intended for continuous service at constant loads, some of the functions of the machine are indefinitely determined. A generator may carry its full rated load until the temperature of all the parts has reached a constant maximum without showing excessive heating in any part, but the same machine may fail in service for some reason which is not developed in the standard ten-hour test. If it is a direct-current machine, commutator troubles may develop, after service of several weeks or months, that gave not the slightest indication during the period of test.

It is to guard against the development of such unforseen troubles that such testing outfits as that described by Mr. Beach, in this issue of the JOURNAL, are designed.

In connection with the flywheel test, which he describes, not only motors but control apparatus can be given endurance runs which so nearly correspond with actual service conditions, that the performance of the apparatus can be foretold with a great deal of certainty. Endurance tests can be made under these conditions, not only with a great deal more satisfaction as regards observation of performance, but with a considerable saving of time as compared with placing the apparatus in actual service.

Any method of testing apparatus, which practically conforms with the service conditions under which it is to operate is certainly to be recommended. Aside from normal operating conditions all apparatus is at times called upon to work under abnormal conditions. The apparatus should be tested for these conditions as well. With a testing apparatus, such as described, not only normal conditions can be established but abnormal conditions as well. Among such abnormal conditions might be mentioned the determination of the length of time the apparatus will carry one hundred per cent above its normal rating; its ability to stand all kinds of abuses that it will be subjected to, such as short-circuits across the motors while standing still, sudden throwing on of the power with the control apparatus on the running position and such other conditions as one experienced in the operation of such apparatus knows it may be subjected to in service.

WILLIAM COOPER

Equipping Electric Cars

Among the many and varied developments and improvements in electric work and machinery that have taken place within recent years, it is a notable fact that the least attention has been paid to the installation of the apparatus in and under electric cars. The method utilized in the days of small cars and light equipments of connecting the controllers to the motors by means of wires loosely bundled together and covered with cotton hose, and held by straps tacked to the car body, has been maintained with very little change. Examinations of the conditions obtaining upon many important city and interurban roads, made during the last few years, have often revealed a state of affairs under the cars, little short of ridiculous, The necessity of radically modifying car wiring was first realized when it became necessary to electrify the elevated roads in the large cities, where the currents to be handled were much in excess of those occurring on the surface lines, and various systems have been developed with the view of increasing the safety and stability of the equipment. It is desirable that the wiring under a car be as nearly fire-proof as possible, and probably the nearest approach to this is obtained by covering the bottom of the car with a fire-proof material and running all the wire in iron pipes. This method is becoming the standard for heavy traction service, and will doubtless be adopted by the more important interurban roads. For light service, much can be gained by judicious use of fire resistant material and flame-proof wires, as well as by intelligent arrangement of the circuits.

The location and installation of the many details that are placed under a modern electric car is often as important as the style of wiring to be used, and the article upon this subject, appearing elsewhere in the JOURNAL, is very timely. R. L. WILSON

The Aim of The Journal

"Your JOURNAL has a distinct field of its own. It should not attempt to broaden its scope in any way which will cause it to deviate from its original aim. Its purpose should be to maintain recognized leadership in carrying out the original idea."

These views were expressed a few days ago by a man who was actively interested in the formation of the JOURNAL, although he has had little to do with it since its publication began.

What was that original idea? The answer awakens some personal reminiscences which may be interesting to the readers of the JOURNAL upon the completion of its third volume.

One evening, a little over three years ago, the board of directors of the Electric Club discussed plans for the coming year. I made some remarks and then added that a good deal of work was done inefficiently.

One of the primary purposes of the Club was to assist its members—principally technical graduates in the apprenticeship course of the Electric company—in acquiring a knowledge of the principles and operation of the apparatus with which they daily worked. A lecture by an engineer had no lasting effect except through the memory of the hearers. Many lectures contained information and data of permanent value. They should be in printed and permanent form. They could then reach all the apprentices. They would be available to men in testing and designing and erection and sales departments, at the factory and elsewhere. Moreover, the same kind of concrete, definite information on apparatus and engineering practice and experience which is suited to the intelligent young man would probably be gladly welcomed by other young men in power houses and in colleges, and by operating and consulting engineers generally. So that a little increase in the initial effort which would put the lecture in printed form would tremendously increase its usefulness. Then again the permanent files of a periodical would make it unnecessary to tediously repeat the same subjects to the new men each year. In addition to Club lectures such a publication could secure many special contributions from a large group of able engineers, it could print articles of counsel and of inspiration, it could be a medium of professional and semi-personal intercourse between writers and readers, it would have unique possibilities for developing as a Journal of the Young Engineer in a field of its own. Such a publication, continued year by year, would result in a valuable reference library of current electrical matters in simple, intelligent form.

Nor was the scheme thus outlined merely a novel idea which occurred at the moment; it was a conviction based upon long observation of the needs of young men who were beginning an engineering career, and so the initial idea of this JOURNAL was not that it might become a pleasing periodical of transient interest; its purpose was serious and its scope far-reaching; its aim was to be of efficient aid to young men and of acceptable assistance to others.

Many have contributed to the development of the JOURNAL, but the fundamental purpose has been to carry out the original idea. The engineering apprentice has been the bull's eye; the product of the new engineering education, the basis of the engineering progress of the future, he is a new factor, a new force in industrial affairs; and in making service to him the editorial criterion, in dealing with the fundamental, the new, the vital and actual things in which he is interested, the JOURNAL finds that it is also producing just the things that are acceptable to a wide circle of readers.

CHAS. F. SCOTT

Who's Who in the Journal

The brief review of the contributors to the JOURNAL during the present year, as presented in this issue, gives our readers a kind of personal introduction to many men whose names are more or less familiar. The list shows that in general, our contributors are in daily touch with the subjects which they treat, and that they are for the most part men who are not in the habit of writing for publication, but are busily engaged in the work of their profession. Such statements as they can take the time to make are generally of the direct, practical kind. This fact is one of the strong features of the JOURNAL, as the articles take on a freshness and an authoritative character, and the subjects are given from the point of view of those who are in touch with the latest developments in electrical work.

In reading over these little sketches it is brought forcibly to mind that here is something that is in line with one of the purposes of the JOURNAL, and that is to be a journal of inspiration. It is certainly an inspiration to read over the various advancements of these young men from the time they took up their engineering work. This is not a selected list but a complete list. These men were not asked to contribute because of their advancement, but because they were in positions to furnish engineering information of value.

In summing up the year's work it is found that of the total contributions for the year, seventy-five per cent are on subjects purely electrical, seven per cent are on engineering subjects other than electrical and eighteen per cent are of a general nature.

Nearly eighty-five per cent of the articles published were prepared especially for the JOURNAL and of the remaining fifteen per cent about half have been revised by their authors for use in the JOURNAL.

A. H. McINTIRE

The English Board of Trade

The recent terrible accident on the West Jersey & Sea Shore Railroad of the Pennsylvania Railroad System, near Atlantic City, brings forcibly to mind the difference between the American and English methods of regulating and controlling public service utilities.

The accident in question had taken place barely two weeks before an investigation had been made by the local coroner, a decision arrived at and the inquiry, as far as the general public was concerned, came to an end.

As it happens, the State of New Jersey has no railroad commission; otherwise, as would have been the case in the State of New York where such a body exists, the commission would have left no stone unturned to determine not only what caused the accident, but also how they could be prevented in the future.

The English method of handling a matter of this sort might well be cited in the case of the accident which occurred on the American special train from Plymouth which was wrecked near Salisbury, England, last summer. This accident was, of course, investigated at once by the local coroner's jury, but no definite result was arrived at as to the cause of the catastrophe. This point was left to the further investigation of the Board of Trade, and this body spent weeks of laborious work and summoned numerous witnesses in a conscientious effort to determine the cause of the accident and to suggest a remedy to prevent its recurrence. The official reports of the board will be made public in due course.

The investigation by the Board of Trade is made on behalf of the Government, and there is a certain satisfaction in the minds of the public in knowing that when such an accident (whether serious or trivial) does occur there will be an investigation of it by the Government authorities.

The English Board of Trade is not a local organization like a chamber of commerce or a builders' exchange such as we have in this country. It is a department of the Government which practically controls all the railways in England, both steam and electric, together with the electric lighting and power companies.

The president of the Board of Trade has a seat in the prime minister's cabinet, and the body as a whole might be roughly compared to our Interstate Commerce Commission and would be practically the same sort of an organization if the Interstate Commerce Commission had control over all public utilities whether they operated solely in one state or in two or more states.

The American method in use in some states of controlling railroads and other public utilities by state commissions is, of course, a step in the right direction, but on account of the varied decisions by the different commissions confusion is liable to occur.

It would certainly seem that an improvement on the American system would be the establishment of some governmental authority, placed possibly under the supervision of the Interstate Commerce Commission, by which all accidents on railroads would be promptly investigated. The need of such a method of supervision becomes more pressing every day, and it is to be regretted that it is very unlikely that the Government will at a very early day take measures of this sort.

As stated recently by the "Engineering News" the attention of all should be forcibly called to the fact that the unfortunate accident on the Atlantic City line had no relation to the fact of electric operation. The published accounts of the same should not permit any misapprehension in this direction to arise. The fact is that the electric equipment had nothing whatever to do with the derailment of the train, and there is no evidence to indicate that a steam locomotive would be more secure against derailment than an electric motor car.

C. S. Powell

A New Index

If the articles published in the first volumes of the Journal be looked over it will be found that a large proportion of its early articles would be acceptable for current issues, had they not already been printed. This is one of the important points in the work of the Journal. It deals with things fundamental, with methods, with actual experiences, rather than with things of a day. It is thus building up in its successive volumes a reference library of practical engineering.

It is the experience of almost every engineer who has occasion to refer to technical periodicals, that it is a very tedious, if not hopeless, task to find information along any desired line when there is a separate index for each annual or semi-annual volume.

To make the information contained in the Journal always available and useful, the topical index scheme was adopted. *A single topical index covers all of the three volumes of the Journal.*

By the use of the Journal topical index it is not necessary to look through a number of volumes, but any article in any volume, along with all articles on the subject, may be quickly located.

Another point is that this index may be arranged as a card index and extended to include any desired number of periodicals or other references.

That the topical index idea has been appreciated by our readers is attested by the fact that the edition issued a year ago, which was supposed to be large enough for all probable needs, was exhausted and a reprint became necessary to supply the demand, until the revised index for the Journal to date is ready for distribution.

A. H. McIntire

ALTERNATING-CURRENT GENERATORS—III

NOTES ON THEIR CONSTRUCTION, PERFORMANCE AND OPERATION

P. M. LINCOLN

PERFORMANCE (continued)

Power-Factor and Rating—When a given number of amperes is delivered at a low power-factor, the generator field current must be increased above that necessary for delivering the same current with non-inductive load, the e. m. f. being the same in both cases. The amount of this increase differs in different machines, depending upon the inherent regulation and the saturation of the field. If the field yoke is nearly saturated when working with non-inductive load, then the increased current will be much larger than is required if the field is not saturated.

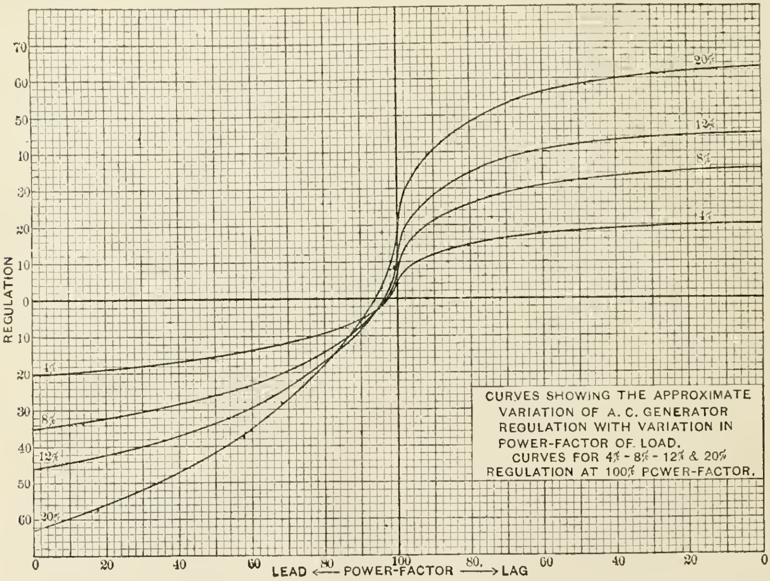

FIG. 18

When there is no saturation of the field yoke or other parts of the alternator, the relative regulations at different power-factors bear definite relations to each other. Fig. 18 shows this relation approximately. Curves are given showing what will be the regulation at any power-factor of alternators having at unity power-factor a regulation of four per cent, eight per cent, twelve per cent and twenty per cent. For other values of regulation at unity power-factor the regulation at other than unity power-factor can be interpolated. The curves show for instance that an alternator having a regulation of eight per cent at unity power-factor has about twenty-one per cent at 90 per cent power-factor lagging, and about twenty-six per cent at 80 per cent power-factor lagging. At about 97 per cent leading current the regulation would be zero; that is, full-load could be thrown off and the voltage would not rise. For lower power-factors leading there would be a fall in voltage when the load was thrown off. In other words, with leading power-factors part of the magnetic flux is due to the armature current. Discretion must be used in applying these curves since they apply only when the magnetic circuit of the alternator is not saturated. They are made upon a basis of two per cent C^2R loss in the armature which is of course excessive for machines of more than a few kilowatts capacity, but since the C^2R loss in the armature has very little effect on regulation the point is not an important one.

The requirements of a generator for delivering a given amount of true energy are very different if this is delivered at an 80 per cent power-factor instead of a 100 per cent power-factor. To deliver, say 100 kw, true energy at an 80 per cent power-factor, will require 125 kw apparent energy. Not only is the current output increased 25 per cent, but there is now a 60 per cent component of the armature current, which is directly opposing the field current. To maintain the same magnetization, therefore, the field must be increased not only for the increased output of 25 per cent, but also for this large demagnetizing element of the armature current.

Automatic Regulation—Other things being equal an alternator of good regulation requires more material and is more expensive than one with a poorer regulation. It is of advantage in cost therefore to secure the element of regulation by some other means than in the inherent design. There are two recognized ways of doing this:

(1) Composite winding.

(2) Automatic regulators.

Composite Windings—Composite windings are applicable only to small machines. It is not usual to apply them to machines above 200 kw, for the reason that the commutation of the compensating current becomes unsatisfactory above this capacity even under the most favorable conditions. No compensating winding is entirely satisfactory because a change in the power-factor of a load not only affects the amount of the compounding obtained but shifts the commutating position of the brushes. Also when used on polyphase machines, a single-phase load on one phase or another changes the compounding as well as the commutating position. As a general rule the smaller the machine the less are the commutating difficulties encountered. The general tendency is to use this method of compounding only on the smaller sizes of alternators.

Automatic Regulators—There are on the market a number of automatic devices which operate to change the field strength of a generator in response to a change in generator voltage. The most successful of these is, without doubt, the Tirrill Regulator now being manufactured by the General Electric Company. This device operates by regulating the strength of the exciter field and uses the change in exciter voltage to oppose the main voltage, thus preventing over-running. This regulator has been very extensively used and has given almost universal satisfaction.

EFFICIENCY—Efficiency is the ratio of the power delivered by a generator to the power which it receives. The power received is equal to the power delivered plus the losses in the machine. The losses are:—

(1) Iron loss, which is approximately constant from no-load to full-load.

(2) Copper loss in the armature, which increases as the square of the armature current. (C^2R).

(3) Copper loss in the field, which increases as the square of the field current. (C^2R).

(4) Friction and windage losses, which are approximately constant at all loads.

The total loss is composed of two constant elements and two variable elements which increase as the machine is loaded, so that the resulting loss increases from no-load to full-load.

The efficiency curve of a machine can be readily laid out if the losses are known. On the other hand, if the efficiency curve is given, the losses at the different loads can be found. For example, if the efficiency of a 200 kw machine at one-half load is 90 per cent, then 100 kw is 90 per cent of the power received by the machine. The power received is therefore one hundred ninetieths of 100 kw, or 111.1 kw, and the loss is therefore 11.1 kw.

Efficiency curves, like abstract mathematical quantities, are of two kinds, real and imaginary. A false efficiency curve may sometimes be detected by determining from it the losses at different loads.

For example, if the efficiency curve of the 200 kw machine above referred to gives 75 per cent at quarter-load, then the power received by the machine at quarter-load is one hundred seventy-fifths of 50 kw, or 66.6 kw. The loss is therefore 16.6 kw, which is considerably greater than 11.1 kw lost at half-load. A machine with a higher loss at quarter-load than at half-load is a monstrosity, and the curve can well be assumed to be an imaginary one.

Specifications for efficiency, especially in engine type machines, should define the method by which the efficiency is to be measured. As it is inconvenient or impracticable to measure the actual power delivered to the machine at full-load, the efficiency can best be determined by measurement of the losses, from which the efficiency can be calculated. The losses are determined as follows:—

Armature iron loss is found by driving the machine, preferably by a motor, and measuring the power required for driving it at normal speed, with field charge to give full voltage, then without field charge; the difference is the iron loss. The power for driving the machine without field charge gives the friction loss, due both to mechanical friction and windage. The copper losses in the armature and in the field are found by multiplying the square of the current in amperes by the resistance in ohms. The sum of these four elements is the total loss. The output divided by the output plus the loss gives the efficiency. The iron loss in the armature is assumed to be constant for different loads. This is approximately true for alternators of good design, but is not true of machines in which there is large field distortion, or in general when the regulation is very poor. In such cases, the loss in the armature teeth increases very considerably as the load increases. The method of determining the efficiency above described is therefore practically correct for machines which have first-class regulation, but it indicates too high an efficiency for machines which have bad regulation.

TEMPERATURE—It is a standard practice to measure all temperatures by thermometers. The temperature of a generator winding may be determined by a measurement of the change in the resistance with change of temperature. Such measurements are, however, very difficult to make, and must be made with extreme accuracy to be of value. Very few stations possess the equipment and very few engineers have had sufficient experience in making close observations to properly conduct tests of such delicacy. For this reason it is much better to trust to thermometer readings, and such is standard practice.

A commonly accepted standard guarantee for revolving field alternators for 2 200 volts or lower include the following specifications for temperature rise, measurement being made by thermometer:

Full-load run for 24 hours, temperature rise not exceeding 40 degrees C.

25 per cent overload for 24 hours, temperature rise not exceeding 50 degrees C.

50 per cent overload for one hour, temperature rise not exceeding 60 degrees C.

This specification is based on rated load in k. v. a. The overload test may follow immediately after the full-load run.

Armature—The temperature of the armature (the conditions of ventilation remaining the same) depends upon the loss in the armature. This is of two kinds: An approximately constant loss in the iron, and a variable loss (increasing with the load) in the copper. The loss in the windings increases as the square of the current. If the current be doubled, the loss is four times as great. If the current is increased 25 per cent, the loss is increased a little more than 50 per cent.

Field—The field temperature depends upon the losses in the field. The losses at full-load depend upon the nature of the load, being greater for loads having low power-factor. The increase of temperature with overloads is approximately proportional to the overload.

For a given total loss the output of an alternator when operating single-phase is about 70 per cent of that operating polyphase. The loss in the armature copper, however, occurs in a smaller volume of copper, and the limiting temperature may be reached in the armature winding when running single-phase before the output has reached 70 per cent normal. Under the head of regulation it was stated that for a given regulation the output of a given polyphase generator running single phase is 70 per cent of the polyphase rating. It is thus evident that both from the standpoint of temperature and of regulation the single-phase rating of a given generator is only about 70 per cent of the polyphase rating.

Time—A considerable overload for a short time may give the same temperature as a small overload for a longer time. Usually, however, the maximum temperature in the copper is quickly reached, so that an excessive overload for more than a few minutes will give an undue rise of temperature in the coils.

Capacity—For a single-phase generator the output is proportional to the product of the current in amperes and the potential in volts. Representing the potential by E and the total current by I, the output in kilovolt-amperes is:—

$$\text{k. v. a.} = \frac{E\,I}{1\,000}$$

For a two-phase generator the total output is equal to the sum of the output of the two single-phase circuits. If the load is balanced, the total generator output is therefore equal to twice the output of each circuit, or k. v. a. $= \frac{2\,E\,I'}{1\,000}$ where I′ is the current in each phase.

With a three-phase generator the problem is not so simple, for there are three circuits to be considered and two methods of winding, the star and the delta. If the generator is balanced, i. e., the load on each phase is equal to one-third of the total load and if E_1, E_2 and E_3, and I_1, I_2 and I_3 represent the potentials and currents of the outside circuits, and e_1, e_2 and e_3, and i_1, i_2 and i_3 corresponding values inside the armature winding, as shown in Fig. 19, then,—

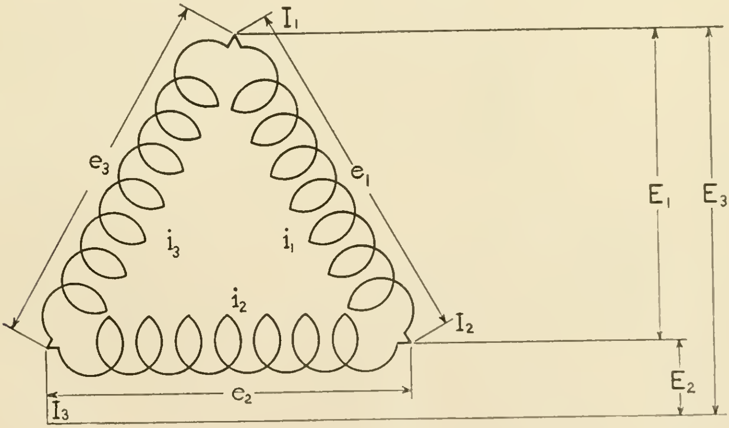

FIG. 19

$$E = E_1 = E_2 = E_3$$
$$I = I_1 = I_2 = I_3$$
$$e = e_1 = e_2 = e_3$$
$$i = i_1 = i_2 = i_3$$

In the delta connections the relations are:—

$$E = e$$
$$I = \sqrt{3}\,i = 1.732\,i$$
$$\text{k. v. a.} = \frac{\sqrt{3}\,E\,I}{1\,000} = \frac{3\,E\,i}{1\,000}$$

In the star connections, shown in Fig. 20, the relations are as follows:—

$$I = i$$

$$E = \sqrt{3}\, e = 1.732\, e$$

$$\text{k. v. a.} = \frac{\sqrt{3}\, E\, I}{1\,000} = \frac{3eI}{1\,000}$$

$$\text{kw} = \text{k. v. a.} \times \text{power factor.}$$

The potential between the side circuits of an inter-connected two-phase generator is approximately 0.7 that across the main line. If a line be taken from the point of inter-connection of the two phases, a five-wire, two-phase system may be operated, supplying three distinct voltages. If a neutral wire be led out through the point of inter-connection of the phases of a star-wound, three-phase generator, the potential between it and any of the main leads is approximately 0.577 that of the main circuits. In power transmission over long distances, a three-phase connection is to be preferred to a two-phase and is generally used in the larger installations. However, where much of the power or lighting is distributed single-phase, a two-phase system is often found more convenient. The performance of two-phase and three-phase generators is practically the same, though a two-phase machine will regulate somewhat more closely under unbalanced loads. The question of which system should be adopted must always be decided by purely local considerations.

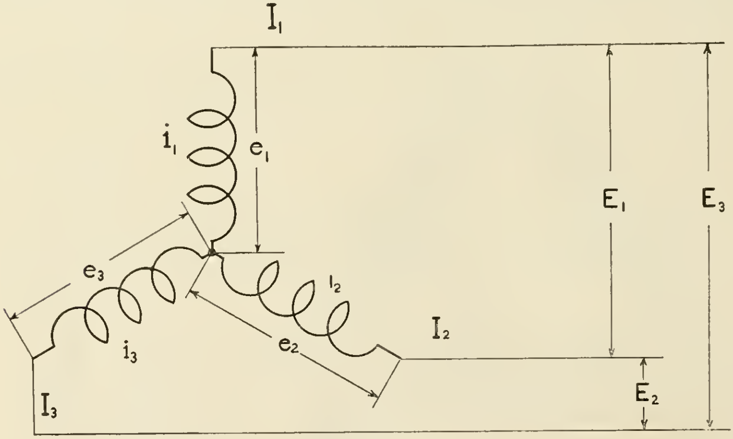

FIG. 20

Power-Factor—When an alternating current and its e. m. f. are in the same phase, i. e., rise and fall in strength exactly together so that maximum, minimum and other corresponding values occur at exactly the same instants, the power in the circuit is the product of the current and the e. m. f.; but when the current lags behind the e. m. f. (as in the case of current flowing to an unloaded induction motor or transformer) or when the current is in advance of or leads the e. m. f. (as in the case of a current to a condenser, to an over-excited generator, an over-excited synchronous motor or an over-excited rotary converter) the power in the circuit is less than the product of amperes and volts by an amount depending upon the nature of the load. The factor by which k. v. a. must be multiplied to give kw is called the power-factor. Power-factor depends wholly upon the nature of the load and the supply circuit, not upon the generator.

RATING—All modern alternators are rated on a kilovolt-ampere basis, not a kilowatt basis. The reason for this is apparent on analysis. The elements of electrical loss in an alternator are the iron loss, which is dependent solely upon the voltage generated, the armature copper loss, which is dependent upon the current through the armature coils, and the field copper loss, which is dependent upon the current flowing through the field coils. To maintain a given current through the armature at a given voltage requires an increasing field strength with a decreasing power-factor. Consequently, for a given kilovolt-ampere output of the machine, the total heat losses are larger for low power-factors than for high power-factors, the difference occurring in the field losses. All other losses of the machine except the field losses are practically independent of the power-factor. For this reason all logical ratings of alternators, are made dependent upon the kilovolt-ampere basis and not upon the kilowatt basis. The power-factor of the load that is to be carried by alternators is therefore an important element in their rating. For instance, an alternator whose field is designed for the limiting temperature rise at 90 per cent power-factor or above will have its kilovolt-ampere capacity reduced at lower power-factors. This point is particularly noticeable with some of the earlier machines which were designed to run on an incandescent lighting load. Such a load has a power-factor of probably 98 per cent or above. If these machines are used to supply a constant alternating-current arc system with a power-factor in the neighborhood of 70 per cent, their capacity is very considerably reduced.

OPERATION

Synchronizing—Two machines are said to be in synchronism when they coincide in frequency and phase. They have the same frequency when the product of the number of poles by the revolutions per minute for each is the same. They are in phase when the positions of the armatures with respect to the field poles are identical, i. e., when similar armature coils are opposite corresponding field poles at the same instant.

The operation of synchronizing consists in bringing the incoming machine up to approximately synchronous speed and to the same voltage as the generator which is running and connecting the two machines together. With the same frequency, the same phase and the same voltage, there will be no unbalanced e. m. f. and consequently no rush of current at the moment of connection. To synchronize two generators it is evidently necessary to provide some means of determining when they are in phase and have the same frequency. The general principle of the most common method of synchronizing is shown in the diagram, Fig. 21.

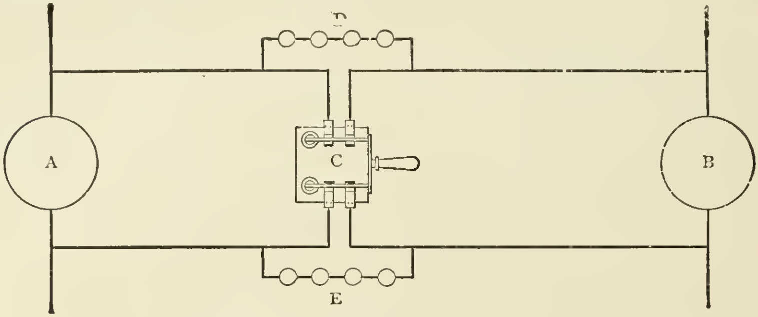

FIG. 21—LAMP METHOD SYNCHRONIZING

A and *B* represent two single-phase machines or a single phase of each of two machines, the leads of which are connected to the switch *C* through two series of incandescent lamps,*D* and *E*. If the e. m. f.'s are in phase and equal, there will be no current in the lamps, but if the generators are not in phase a current will flow through the lamp circuits and, as the difference in phase increases, the lamps will light up and become brighter until a maximum is reached, when the phases are in exact opposition. As the difference in phase decreases, the lamps will decrease in brilliancy until darkness indicates that the generators are again running in phase. The rate of pulsation of the lamps depends upon the relative frequency of the generators being synchronized.

The synchronizing device, instead of being connected directly across the two circuits, may be connected in the secondary circuit of two shunt transformers, as shown in Fig. 22. If the transformers are similarly connected, there will be no current through the lamps when the machines are in phase, since the e. m. f.'s of the two transformers will be opposed, as shown by the arrows in the diagram. When the generators are out of phase the e. m. f.'s will be out of phase also and current will flow through the lamps, its amount and the resulting brilliancy depending upon the difference in phase.

If the connections of either the primary or secondary of either transformer be the reverse of that shown in the diagram, the indication of the lamps will be reversed, i. e., they will burn at a maximum brilliancy when the generators are in phase. This arrangement is generally to be preferred.

Synchronizer and Synchroscope—Although lamps are often used for synchronizing, the method is not safe practice for high voltage generators, nor wholly suitable for low voltage machines, as the lamps do not determine the exact time of phase coincidence and there is always the possibility of connecting the two machines when a considerable difference of phase exists. The ideal synchronizer should perform three distinct functions: First, it should indicate whether the incoming machine is running too fast or too slow; second, it should indicate the amount the incoming machine is running too fast or too slow; third, it should indicate the exact instant of synchronism. These functions are performed with perfection by the synchroscope, and the use of either this instrument or the automatic synchronizer should always be recommended.

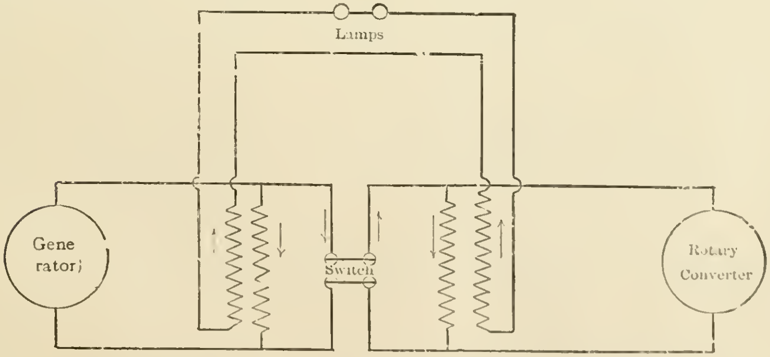

FIG. 22—TRANSFORMER AND LAMP METHOD OF SYNCHRONIZING

Adjustment of Field Current—When the rheostats of two alternators running in parallel at normal speed are not adjusted for the proper field current, an idle or cross current flows through the armatures, the amount of which depends entirely upon the difference in the field charges of the machines and may vary over a wide range, from a minimum of zero when both field charges are uniform to more than full-load when they differ greatly. The effect of this current is to increase the temperature of the armature and, consequently, to cut down the output of the machine. It is therefore desirable that the rheostats be adjusted so as to reduce it to a minimum. This cross current is registered on the ammeters of both machines and so increases both readings. The sum of the ammeter readings will be a minimum when the idle current is zero. In general, the proper field charge of a machine running in parallel is that which it would have if it were running alone and delivered its load at the same voltage.

Fly-Wheel Effect—To prevent excessive cross currents between alternators they must not be allowed to depart materially from the same relative phase position. When running from an engine, therefore, the energy that is supplied intermittently by the piston must be partially stored in a fly-wheel when the energy supplied by the piston is a maximum and then delivered by the fly-wheel to the alternator when the energy supplied is a minimum. To prevent excessive cross currents between alternators, the fly-wheel must be of such dimensions as to prevent a departure from normal uniform velocity of more than three electrical degrees. The proper amount of fly-wheel effect to accomplish this will depend upon the uniformity of rate of energy supplied. The fly-wheel effect of an armature is an item of information that should always be supplied to the engine builder, for engine type machines. This enables the engine builder to calculate the proper size of fly-wheel to add to the outfit to meet the following specifications of uniformity.

Engine Requirements—Steam engines driving alternators should have the following characteristics:

(a) The engine governors should be so constructed that there will be no tendency to cause a periodic transfer or surging of the load between one engine and another. This tendency may originate in the angular variation of velocity in different parts of the revolution which is common to all reciprocating engines, or to a sudden variation of load which will affect each governor in a slightly different manner, or to other causes that lead to a non-uniform speed. The engine governors should not be sensitive to such disturbances and should not maintain or increase them.

The effect on the engines of a periodic transfer of load occasioned by hunting between two engines running in parallel, is somewhat similar in effect to throwing the load on or off a single engine at short equal intervals, which may be measured by one or several pulsations in the combined turning efforts applied to the engine shaft.

In some extreme conditions the pulsations of load may amount to more than the normal capacity of either engine. With no external load one engine may then alternately drive the other, which will evidently be a more severe condition than if the load were only applied and removed from a single engine.

If under any case of pulsating load the engines do not tend to accentuate the pulsations in turning effort and speed, then a condition favorable to parallel running is attained.

(b) Variations in the angular velocity of the rotating part of a generator through a revolution at any constant load not exceeding 25 per cent overload should not exceed one-sixtieth of the pitch angle between two consecutive poles from the position it would have if the motion were absolutely uniform at the same mean velocity. The maximum allowable variation, which is the amount the rotating part forges ahead plus the amount which it lags behind the position of uniform rotation, is therefore one-thirtieth of the pitch angle between two poles.

In a two-pole machine this variation is equivalent to three degrees as measured on the circumference of the rotating part; in a four-pole machine it is one and one-half degrees, and in a six-pole machine one degree, or as the number of poles increases the permissible angular variation decreases.

(c) Engines that are used for parallel operation should have practically the same characteristics of speed regulation in order that the power delivered to their respective generators may be proportional to the load, that is, the same load on any engine should produce the same percentage drop in its speed. This is most readily obtained with engines in which at full-load the speed drops from three to five per cent below the no-load speed, as a slight change in adjustment of the governor will have less relative effect than with engines in which the speed drops only one per cent under the same variation of load.

(d) The use of governors which are adjustable while the engine is running is advisable, as slight adjustments of speed may then be made which will facilitate synchronizing the alternators or changing the load carried by the engines.

Maximum Permissible Variation on Either Side of Uniform Rotation:

Poles	Angular Degrees	Per Cent of Circumference	Poles	Angular Degrees	Per Cent of Circumference
2	3.000	0.8330	42	0.143	0.0395
4	1.500	0.4160	44	0.136	0.0380
6	1.000	0.2770	46	0.130	0.0360
8	0.750	0.2080	48	0.125	0.0345
10	0.600	0.1660	50	0.120	0.0335
12	0.500	0.1390	52	0.115	0.0320
14	0.430	0.1190	54	0.111	0.0310
16	0.375	0.1040	56	0.107	0.0295
18	0.333	0.0920	58	0.103	0.0285
20	0.300	0.0835	60	0.100	0.0280
22	0.270	0.0750	62	0.097	0.0270
24	0.250	0.0695	64	0.094	0.0260
26	0.230	0.0640	66	0.091	0.0250
28	0.210	0.0595	68	0.088	0.0245
30	0.200	0.0555	70	0.086	0.0240
32	0.187	0.0520	72	0.083	0.0230
34	0.177	0.0490	74	0.081	0.0225
36	0.167	0.0465	76	0.079	0.0217
38	0.158	0.0440	78	0.077	0.0211
40	0.150	0.0415	80	0.075	0.0206

Hunting—The object of the preceding specifications is to obtain a generating system that will have a minimum tendency to hunt or pump. Hunting is a condition in which there is a periodic exchange of current or energy between generators or other synchronous apparatus on the same system. Hunting usually manifests itself by periodic fluctuations of the instruments, undue heating of the apparatus, or by periodic sparking. Its almost universal cause is periodic fluctuations in the supply of energy to the circuit. In a steam engine, for instance, the rate of supply of energy to an alternator during the instant following admission of steam to a cylinder is much greater than during the instant preceding admission. Since the electric circuit has no capacity for storing energy the fluctuations must appear either as changes in the output of the generator or as changes of speed in the flywheel attached to the generator. In either case there is a tendency to set up a condition of hunting. The amplitude of the hunting effect will depend upon the violence of the fluctuations of energy input and upon the ability of the generating system to damp out the hunting. If the generators, synchronous motors and rotary converters are provided with dampers of good design the tendency to hunt will always be diminished and generally eliminated. If there are no dampers, however, hunting once started is apt to become cumulative, and to go rapidly from bad to worse until some of the apparatus falls out of step.

Synchronous motors are more subject to hunting than generators as they are apt to be at the ends of transmission lines having considerable loss. This condition increases the tendency to hunt. The greater the line loss the greater the tendency to hunt. No exact limit to line drop can be set beyond which hunting is sure to occur since hunting is dependent on other things besides line drop. Tests seem to show, however, that with line drops of twenty-five per cent and above it is difficult if not impossible to design synchronous apparatus that will not hunt.

Excitation—The amount of exciting current required by an alternator is a function of the number of poles, the size and regulation of the machine. A brief analysis will show the reason for this. It requires a certain number of ampere turns to force a given magnetic flux through a given magnetic circuit. Two magnetic circuits will require double the ampere turns; therefore, the exciting current will increase with the number of poles, other things being equal. Also, it requires practically the same number of ampere turns to force a given flux density through a magnetic circuit, no matter what the area of the magnetic circuit; therefore, the relative magnetizing energy will decrease as the size of an alternator increases, other things being equal.

Small machines of many poles require large exciting power, and large machines of a small number of poles require comparatively small exciting power. Two per cent of the output is often taken as the exciter capacity of alternators. For low speed, high frequency alternators this is a little low, while for low frequency, high speed turbine type generators it is much too high. One half per cent, for instance, is sufficient for a 6 000 kw, four-pole 1 500 r. p. m. turbo-alternator.

THE ORGANIZATION OF THE ELECTRIC COMPANY

E. M. HERR,
First Vice President

IN opening an informal presentation before the Electric Club of "The Organization of the Electric company," with particular reference to the inter-relations of the various departments, Mr. Herr spoke of the importance of an organization in any business. He emphasized the extreme value of the skilled and trained members, or personnel, in any organization as compared with the inert or material parts, such as buildings and machinery. The latter money can replace, but no amount of money, and only much patient and skillful personal effort over a long time can replace the trained and experienced men and women in any organization for manufacturing or engineering.

Again, things and people differ in this: one is passive, the other active; one is constant and dependable, the other is subject to change without notice; machinery remains, people come and go. Hence the human element enters. Our capacity, mentality and moral relations are not perfect. Care is required not only by those who are in charge, but each part needs to exercise its own intelligence and individuality.

Mr. Herr then gave a brief account of the farmation of the Electric company and an outline of its organization and various departments.

First are the stockholders or owners, and then the board of directors, then follows the executive branch, including the chief officers constituting the management of the company.

The principal departments are the sales, the engineering, the works, the financial and the accounting department.

The sales department is divided into three divisions, the railway and lighting, the industrial and power and the detail and supply, the managers of which are located at East Pittsburg. There are twenty-two district offices and an export office. The price department is closely related to the sales department.

The engineering department is divided into six main divisions, the power, the industrial, the railway, the detail and supply, the transformer and the research division, each dealing with a particular class of work. The draughting division falls under this department, and closely related in work are also the erection and railway construction departments.

The works department includes the works at East Pittsburg and Newark and the Allegheny and Cleveland foundries. This department is under the direction of the manager of works, with a number of immediate assistants in charge of production and of tools. There is a superintendent with several assistants at East Pittsburg; then follow the general foremen, the foremen and the workmen, in some twenty-five sections of the works. The inspection and testing departments and the engineer of works, having in charge the alteration to machinery and buildings, also report to the manager of works. The storekeeper, having in charge the supplies for manufacture and completed apparatus, and also the rate department, and the watchmen and janitors likewise report to the manager of works. The Newark works and the foundries have their own superintendents and assistants.

The financial department is in charge of the treasurer, with assistants, and a credit manager.

The accounting department is in charge of a general auditor, with assistants.

In addition to the foregoing are the legal department, dealing both with commercial law and patent matters; the purchasing department, through which all purchases of materials are made; and the general departments of publication and publicity, having in charge advertising, convention exhibits, catalogues, technical writing and the like.

The correspondence department with several divisions for handling different classes of apparatus, is the focal point through which passes the incoming and outgoing business between district offices and customers and the various departments of the works.

In general, the principal departments report directly to one of the vice presidents of the company. Mr. Herr indicated the various functions of these departments, taking up broadly the character of their work and the relation of one department to the other. He then addressed particularly the technical graduates, who comprised a large proportion of his audience. His remarks to them were substantially as follows:

I want to address a few words to the technical graduates. I am especially interested in them. I was one myself, not in electrical engineering but in mechanical engineering. I went through the shop much as you are now doing, and I can assure you that you are now doing something that you will always be glad of, and the better you do your work the gladder you will be that you have done it. The opportunity to do it comes but once. You can "get next" to shop work and see how it is done and you can work on equal terms with the workingman, learning what a substantial and intelligent fellow he is and getting his point of view. You should take the whole course, because you will need it before you are through. In my own apprenticeship I had one year at five cents per hour, nine hours per day, and a second year at seven and a half cents per hour. Do not try to make money now; this is the time to gain working capital in the way of experience.

Look carefully to the possibilities for advancement in the works. Most young men look with especial favor to some line of engineering work or to the sales department. The growth of the modern factory has created a new need for well trained men practiced in machine shop work who have executive ability. Not enough attention has been given to the training of high-grade mechanics, and it is not unlikely that we may suffer for the want of them. There are many opportunities opening in the practical management of shop affairs. It is sometimes felt by young men that they cannot so readily attain positions of responsibility in the works management as they can in other departments. The reason is obvious. Technical graduates have already spent several years in technical schools in a kind of training which is really an apprenticeship in engineering. They therefore begin their practical work with a fair training along engineering lines, while in shop work they must begin a new kind of apprenticeship course, starting lower down.

Don't be afraid to teach somebody how to do something—the day of narrowness and exclusiveness is past. Efficiency in a large organization requires team-work and co-operation. And then, again, you never know a thing so well as when you have told it to somebody else. The habit of helping the other fellow will help you more than it does him.

A fundamental essential in a large organization is a healthful esprit de corps. It is of first importance to get the right spirit, so that every fellow is pulling the right way and pulling hard. No big man can himself alone do much in a big organization, it is united individual effort which produces results.

Do not build a fence around yourself; do not be exclusive. It is true that every man has his own job and others must not interfere with his work. On the other hand, lend aid and encouragement when the other gets stuck; be ready to help him out.

An incident which occurred some years ago illustrates what I mean by the right spirit on the part of the men who make up an organization. It became necessary for the railroads to economize during hard times. One road devised a plan for saving fuel. This was explained to the officers of another road and the possible economy was recognized. On the first road the engineers were brought to take an active interest in the work. Performance sheets of engines were posted each month and carefully scanned. The engineers vied with each other to improve their record. As a result over $160,000 was saved in one year. On the second road, no economies were effected. The engineers were not brought into sympathy with the scheme and made no real effort to carry it out. This incident illustrates the point which I want to enforce, namely, the value of esprit de corps throughout an organization and the need of fostering a proper attitude of each man in an organization to his work and to his fellows.

THE STANDARDIZING LABORATORY—II

A SPECIAL POTENTIOMETER

H. B. TAYLOR

THE special features of the potentiometer described below, consist in an arrangement of connections which make it convenient for use in measuring resistance as well as voltage and current and in the unusually high insulation between parts. The extra insulation was necessary because the instrument was for use at East Pittsburg, where the atmospheric conditions are particularly unfavorable for the operation of instruments which are affected by leakage currents. At certain seasons of the year the air is very damp and it is never clean. Exposed surfaces quickly receive a deposit or film of dirt which is far from being a perfect insulator.

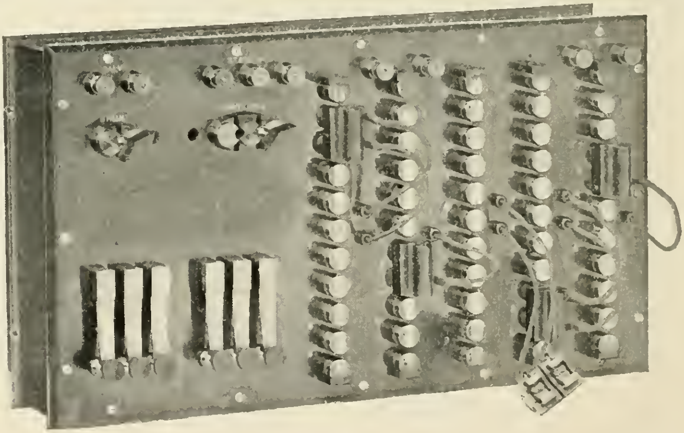

FIG. 1—VIEW OF TOP OF POTENTIOMETER

INSULATION

No trouble from leakage currents through the insulating material itself is ordinarily experienced with any potentiometer. The leakage occurs over the surface between metal parts on the outside. In order to obtain good insulation only such metal parts as are necessary were mounted on top of the case and the metal surface distance between these was made great enough to prevent serious leakage. Special care was taken to arrange the instrument so that these insulating surfaces could be easily cleaned.

The top of the case, as shown in Fig. 1, is of hard rubber. Each metal part is mounted on a separate hard rubber base 0.3 inch high. These bases fit closely to the top of the box and each has a thin layer of white shellac underneath, to make a moisture-proof joint. The object of the separate bases is to increase the surface distance between the metal parts by twice the height of the base. Many of the metal parts are separated by a 0.25 inch air space, which makes the surface distance between them 0.87 inch. All parts inside the case which are close together, or which it is important to keep well insulated are provided with hard rubber washers. Nearly all of the inside connections, as shown in Fig. 2, were made with bare wire of a size large enough to stay rigidly in position without any other support than at the points of electrical connections. After connections had been completed, all inside parts, including hard rubber and wooden surfaces, were given several coats of white shellac.

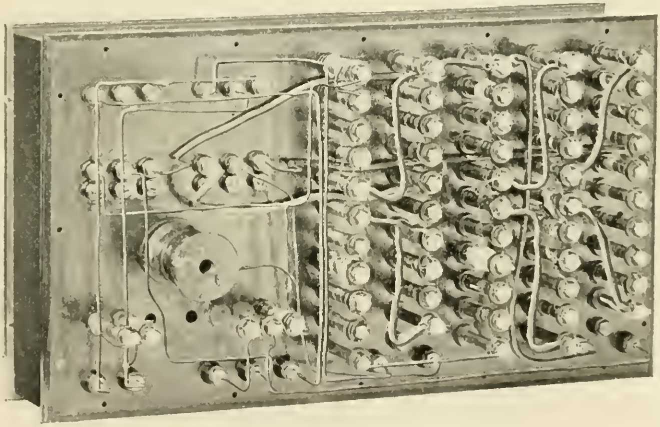

FIG. 2—VIEW OF INSIDE OF POTENTIOMETER

The diagram, Fig. 3, shows the general plan of the instrument, the scheme of connections of main resistance and vernier coils being that in common use in potentiometers. A battery is connected through a rheostat to a fixed resistance. The current is adjusted by means of the rheostat until the voltage drop across this resistance is exactly equal to a standard voltage which is connected in the opposite direction through a galvanometer and keys. The condition of equality exists when the galvanometer does not deflect on pressing the keys. Having established the voltage across the total resistance, the voltage across any part of it is a definite quantity. The various steps are marked on the instrument in their proper proportions, reading in decimals from left to right.

The voltage X, to be measured is applied to part of the resistance, also through a galvanometer, and keys and the contacts through which it is applied are moved so as to change the resistance between them without changing the total resistance, until a balance is obtained. By means of the vernier coils, the small drop of voltage across one of the main coils is divided and subdivided until exceedingly fine adjustments can be obtained.

As is customary, the total resistance used in measuring the voltage was made an odd number of ohms to correspond with the odd voltage of the standard cell. A Weston standard cell having an e.m.f. of 1.0198 volt is used. The resistance across which it connects is 10 198 ohms. This gives 0.1 milli-volt per ohm or, in other words, the current required to produce a balance is .0001 ampere. The total resistance used with the cell is composed of the main resistance of 9 999.9 ohms in the potentiometer coils and 198.1 ohms additional required to make the instrument direct reading when used with a 1.0198-volt cell. If a cell of some other constant voltage were to be used, the only adjustment necessary would be to change the resistance of the 198 ohm coil. To do this is only a few minutes work and is so seldom necessary that no provision was

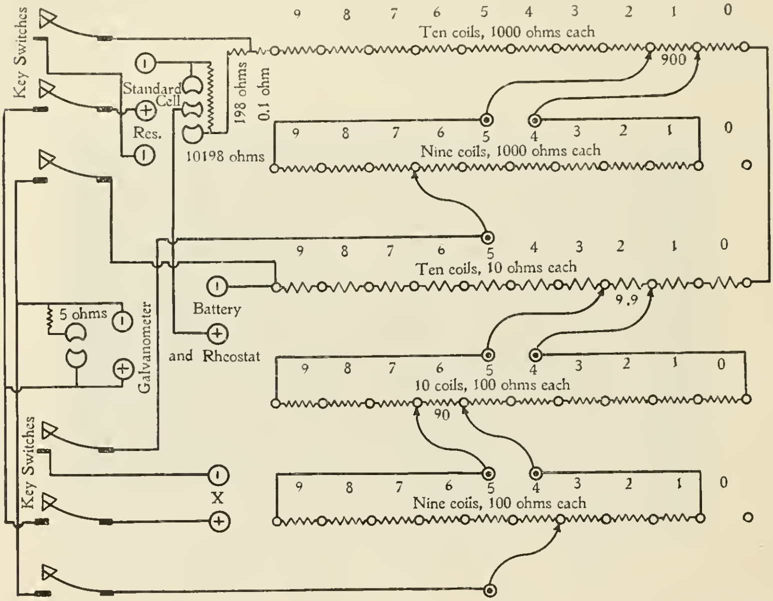

FIG. 3—DIAGRAM OF CONNECTIONS

made on the top of the instrument for adjustment for different voltages.

The 10 198 ohm coil connected across the two-plug receptacle was intended for use chiefly as a protective resistance for the standard cell. As the protective resistance could not very well be dispensed with, it was made of manganin wire like the other coils and its resistance adjusted accurately in order that it could be used in other ways, if desired.

The ordinary procedure in making a measurement is to take the plug out of the left side of the two-point receptacle and put it in the receptacle for closing the galvanometer shunt circuit until after the first steps of the adjustment have been made. It is then put back in place. A plug is kept in the right-hand side of the two-point receptacle all the time unless it is desired to use two standard cells in series or else to double the potentiometer reading corresponding to a given voltage. In either event a plug would be put in the left side only. The former use would be made when two cells were available, neither of which had e.m.f. as near 1.0198 volt as the average of the two. The latter plan is used in measuring extremely low voltages. With a sufficiently sensitive galvanometer, readings can be taken which would fall between two adjacent figures in the last row as ordinarily connected.

The potentiometer coils are arranged in five straight rows and connections are brought out to brass terminals at the top. The movable contacts are mounted in hard rubber blocks which slides along the top of the brass contact pieces. A transverse slot in the lower part of each block serves to increase the surface distance between brushes to about one inch. Contact with the brass pieces is made at the top and both sides. The top contact is made through laminated copper brushes; that at the sides through clips of spring brass, which work in a row of slots on the sides of the cylindrical brass contact pieces. The clips serve as a guide to keep the hard rubber block in place and also indicate when the contacts are in the proper position. They make a snug fit when in position and a loose one when in middle position, enabling the operator to locate the contacts properly without looking at the instrument. The view in Fig. 1 shows one of the blocks removed from its position and turned over to give a view of the brushes and clips. Flexible leads long enough to allow the necessary travel connect with the brushes. Where these pass through the top of the box a bushing one inch long is provided. The lower end of the bushing is sealed with shellac.

For the sake of simplicity in operation as well as to promote insulation, two sets of keys were used instead of one or two keys with a two-way switch. In measuring voltage only two of the keys in the set at the left need be used, but all three keys in the set to the right are required. The set at the left is used in adjusting the battery current to balance the standard; the other set in balancing *X*.

Having ascertained by trial that the relative directions of all e.m.f.s are right, the resistance is adjusted until the galvanometer does not deflect when the keys at the left are closed. Then with the keys at the left open, the other set is closed momentarily and the positions of the contact blocks changed according to the direction indicated by the galvanometer, in the same way as the positions of plugs are changed in measuring resistance with a Wheatstone bridge, until a balance is again obtained. As the movement of the contacts does not affect the total resistance in circuit, the balance with the standard cell should not be affected. It is safest to verify this by closing the first set of plugs again. The maximum e.m.f. which can be measured on the potentiometer proper with one standard cell, is practically one volt. The range can be doubled by using two standard cells in series, but the usual way of measuring e.m.f.s above one volt requires a resistance box in connection with the other apparatus. The e.m.f. is applied to a certain resistance which may be as high as desired and is usually large enough to keep the current below 0.01 ampere. Taps from a known part of this resistance, preferably a decimal part, are run to the *X* connections of the potentiometer. The potentiometer reading will be the total e.m.f. multiplied by the ratio of the resistance of the section between the taps to the total resistance.

MEASURING LOW RESISTANCE

The most noteworthy feature of the instrument is its application to measuring low resistance. To do this the resistance X to be measured is connected in series with the standard resistance. If the standard is of higher resistance than X, connections are made from its potential terminals to the binding posts marked *Standard Resistance* and from the terminals of X to the binding posts *X*. The resistance of these connections does not enter into the results, as they are potential leads only and do not carry current when a balance exists. Enough current to give between one-tenth volt and one volt drop across the standard is passed through two resistances. The rheostat in the potentiometer circuit is adjusted until a balance with the standard is obtained in the same way as though a standard cell were used. As shown in the diagram, the potentiometer resistance connected to *Standard Resistance* binding posts is 10 000 ohms. The reading across *X*, therefore, is a decimal of the standard. Multiplying the resistance of the standard by this decimal gives the resistance of X. If standards of 0.1, 0.01, 0.001 ohm, etc., are used, all that is necessary is to note the reading and to locate the decimal point where it belongs.

When it is necessary to use a standard of lower resistance than X, the positions of X and the standard are interchanged. The resistance of X in that case is found by dividing the resistance of the standard by the potentiometer reading. In order to eliminate thermo-electric and similar errors in work requiring the highest precision, both batteries are reversed and a second reading taken. The average of the two readings gives the correct result.

ADVANTAGES OF METHOD

This method has several advantages over the well known Thomson bridge method of measuring low resistances.

None of the resistances of connections enter into the calculation of results and no change of ratio-coils is required, whatever the range of resistance to be measured.

Accurate comparison can be made between resistances which differ greatly.

All kinds of resistance, solid or liquid, can be measured.

ACCURACY AND SPEED

The Thomson bridge has an advantage in not requiring steady current. With current from a storage battery the time required for making an observation by either method is about the same.

Probably the best way to convey an idea as to the accuracy attainable is to give an example of measurements which have been made. Between August, 1905, and September, 1906, a certain set of low resistance shunts have been checked at intervals of three weeks by this method. Their nominal resistances are 5, 1, 0.1, 0.05, 0.01, 0.005, and 0.0025 ohm. Comparisons with a 10 ohm and a 0.001 ohm standard were made without reference to any other standards. Sometimes the comparisons would begin at one end of the series and sometimes at the other. The resistance of the 0.0025 ohm shunt would be determined by comparison with the 10 ohm or the 0.001 ohm standard. Using the resistance thus found, the second of the series would be calibrated by comparison with the first, and so on throughout the eight measurements. If there was no error, the resistance of one standard as determined from the other through the series of steps should check with its known resistance. In nearly all cases it did check within 0.02 per cent. The maximum discrepancy ever found was 0.043 per cent. The average error per reading was unquestionably much lower than these totals. The measurements were made by several different men, under ordinary working conditions. Only one set of readings was taken on any given date. Had greater precision been necessary the average of three or four readings would have been taken.

In general there is no difficulty in determining the ratio of two resistances within 0.01 per cent if one is not more than ten or fifteen times the other. Ratios as high as 1 000 to 1 are readily measured within 0.1 per cent. In both instances it is assumed that a drop of voltage of at least 0.1 volt across the higher resistance is permissible.

BATTERY

There is a general impression that storage cells are the only batteries that are suitable for supplying the e.m.f. to balance that of the standard cell. Experience with a considerable variety of cells has failed to show any advantage in using storage cells or even primary cells designated for closed-circuit working. The current required is so small that there is no trouble due to polarization. Ordinary zinc-carbon cells have given as good results as any. An old Carhart-Clark standard cell which had been worn out so far as its use as a standard was concerned supplied the current during working hours every day for about three months and gave entire satisfaction.

Whatever type of cell is used it must be perfectly insulated from everything except its own circuit and should be located where its temperature will be as nearly constant as possible.

ENGINEERING TRAINING

The dedication of the new Engineering Building of the University of Pennsylvania was held on October 19th, 1906, and was attended by a large number of invited guests from various schools, societies, etc., and also by representatives from various foreign countries. This building is said to be the finest building of the kind in existence and to have cost, including equipment. nearly one million dollars. The principal addresses at the dedication ceremonies were made by Mr. Frederick W. Taylor, President of the American Society of Mechanical Engineers, and by Dr. Alexander C. Humphreys, President of Stevens' Institute of Technology, from which the following extracts are made.

A COMPARISON OF UNIVERSITY AND INDUSTRIAL DISCIPLINE AND METHODS

FREDERICK W. TAYLOR

The point from which I view college education is that of the employer, not that of the educator. I have had no experience with the difficult and complicated problem that faces the professors and the governing boards of our colleges. I have been engaged for years in organizing the shop, office and commercial management of quite a wide range of engineering and manufacturing establishments. This has brought me into intimate personal contact with a large number of college graduates, and I have become well acquainted with their strong points, which are many, and at the same time with a few of those points in which it would seem that as a class they might be improved. Something may possibly be gained by considering what has seemed to many of the friends of our young graduates to be the one defect which they practically all have in common.

For a period of from six months to two years after graduating they are, generally speaking, discontented and unhappy. They are apt to look upon their employers as unappreciative, unjust and tyrannical, and it is frequently only after changing employers once or twice and finding the same lack of appreciation in all of them, that they finally start upon their real careers of usefulness.

On the other hand, the attitude of employers towards young graduates is fairly expressed by the following written instructions given for the selection of quite a large number of young men to fill positions which presented opportunities for rapid development and advancement. These instructions were to give the preference—first, to graduates of technical schools; second, to the graduates of the academic departments; but to employ no college boy who had not been out for more than two years.

Why is it, then, that these young men are discontented and of practically little use during the first year or two after graduating?

To a certain extent this is unquestionably due to the sudden and radical change from years spent as boys almost solely in absorbing and assimilating knowledge for their own benefit to their new occupation of giving out and using what they have for the benefit of others. To a degree it is the sponge objecting to the pressure of the hand which uses it. To a greater degree, however, I believe this trouble to be due to the lack of discipline and to the lack of direct, earnest and logical purpose which accompanies, to a large extent, modern university life.

During the four years that these young men are at college they are under less discipline, and are given a greater liberty than they have ever had before or will ever have again.

Is not the greatest problem in university life, then, how to animate the students with an earnest, logical purpose?

In facing this question I would call attention to one class of young men who are almost universally imbued with such a purpose; namely, those who, through necessity or otherwise, have come into close contact and direct competition with men working for a living. These young men acquire a truly earnest purpose. They see the reality of life, they have a strong foretaste of the struggle ahead of them, and they come to the university with a determination to get something practical from the college training which they can use later in their competition with men.

They are in great demand after graduating, and as a class make themselves useful almost from the day that they start in to work.

Neither their earnestness or purpose, however, nor their immediate usefulness, comes from any technical knowledge which they have acquired while working outside of the university, but rather from having early brought home to them the nature of the great problem they must face after graduating. Nothing but contact with work and actual competition with men struggling for a living will teach them this. It cannot be theorized over or lectured upon, or taught in the school-workshop or laboratory.

I look upon this actual work and competition with men working for a living as of such great value in developing earnestness of purpose that it would seem to me time well spent for each student, say, at the end of the Freshman year, to be handed over by the university for a period of six months to some commercial, engineering or manufacturing establishment; there to work as an employee at whatever job is given him, either manual or other work. He should have the same hours and be under the same discipline as all other employees, and should receive no favors. Moreover, he should be obliged to stay even a longer time than six months unless he has in the meantime given satisfaction to his employers.

I believe that there would be but little difficulty in obtaining the co-operation of our business and manufacturing establishments in carrying out this plan.

My belief in the benefits to be derived from doing practical every day work early in the college course is not the result of a theory. It is founded upon close observation and study of young men who have had this experience, and also upon a vivid remembrance of breakfasting each morning at five-thirty, and starting to sweep the floor of a pattern shop as an apprentice some thirty-two years ago, after having spent several years in preparing for Harvard College. The contrast between the two occupations was great, but I look back upon the first six months of my apprenticeship as a patternmaker as, on the whole, the most valuable part of my education. Not that I gained much knowledge during that time, nor did I ever become a very good patternmaker; but the awakening as to the reality and seriousness of life was complete, and, I believe, of great value.

Unfortunately, laboratory or even shop work in the University, useful as they are, do not serve at all the same purpose, since the young man is surrounded there by other students and professors, and lacks the actual competition of men working for a living. He does not learn at college that, on the whole, the ordinary mechanics, and even poorly educated workmen, are naturally about as smart as he is, and that his best way to rise above them lies in getting his mind more thoroughly trained than theirs, and in learning things they do not know. All of this should be taught him through six months' contact with workingmen.

Let me repeat that our college graduates are the best picked body of men in the community. I believe that it is possible to so train young men that they will be useful to their employers almost from the day that they leave college; so that they will be reasonably satisfied with their new work instead of discontented; and to place them upon graduating one or two years nearer success than they now are; and that this can best be accomplished by giving them an earnest purpose through six months' contact early in their college life with men working for a living; by rigidly prescribing a course of studies carefully and logically selected, and with some definite object in view, and by subjecting them to a discipline comparable with that adopted by the rest of the world.

THE ENGINEER AS A CITIZEN

ALEXANDER C. HUMPHREYS

The engineer, to be an engineer in anything more than title, must be practical. His work must be based upon correct and complete theory, but it must be first and last practical. Can the engineer be practical, can he economically apply the truths of nature for the benefit and convenience of mankind; in other words, can he really be an engineer unless he is competent to practice his profession within the necessary commercial limitations and in accordance with standard business methods? Can he disregard the question of return on investment? These questions, if fairly put, answer themselves. But still there are engineers who seem to believe that engineering is something which can be practiced without regard to money values and that others can be trusted to co-ordinate the engineering and commercial elements of the enterprises in which they are concerned. These men may be ingenious mathematicians, they may even be eminent as scientists, but they are not engineers. The man who is willing to spend a dollar scientifically to save fifty cents cannot be classed as an engineer. The man to serve the cause of truth must be fully qualified to practice his profession in conformity with the limitations of commercial and industrial practice: to the knowledge and training gained in the school of engineering he must have added that knowledge and training which is to be gained only in the exacting school of experience.

We must encourage ourselves in the reflection that our engineering courses are, after all, preliminary, and to a certain extent, elementary, and that it must in any case remain for each student after graduation to learn thoroughly all the details of some one—possibly narrow—branch of engineering or industrial operation. While every engineer-student should, after four years, have a good general knowledge of engineering science and practice and be thus prepared to acquire rapidly and surely a specific and certain control of some one branch of the profession, we must recognize that we cannot graduate our men as fully equipped engineers, ready to assume positions of responsibility in any part of the engineering field. And are not the employers often at fault, even some of those who themselves are graduates in engineering, in expecting the young graduate to be able at once to do work which probably the employer himself was not qualified to do for years after his graduation? Is not too much expected of the modern education? There is no royal road to learning; there never will be, and no progress in educational methods will ever relieve the students from the hard work required for mental discipline and specific training.

Is it not probable that in certain directions we are giving our students more than they are yet prepared to assimilate and organize as a basis for action? Should they not be subjected to a well-balanced course? Should they not then at least be taught the necessity for practicing in conformity with commercial limitations and methods?

I contend that every engineer-student should have some instruction in the principles of accounting, in depreciation, business law, patent law, banking, specification, and even of sociology. And in connection with the business side of their training they should be made to see the importance of the correct use of language. They should be given opportunities to see how the work of the world is impeded and hindered through the ambiguous expression of thought. They should be taught that it is not enough to know, but that they must be able to give effect to their knowledge through the use of correct, clear, explicit and forcible language. More particularly in this business department they should be warned by those who can speak from experience of the pitfalls into which they are liable to fall and especially through the efforts that probably will be made to purchase their professional opinions if these opinions prove to be of value. Here, as in no other department, can the ethics of the profession be impressed upon the young engineer-student. As religious instruction is excluded from engineering courses, it is all the more incumbent upon us to show our students the lines along which they should practice if they wish to maintain their self-respect.

Some authorities oppose the broadening of our schemes of instruction on the score that necessarily the effect must be to make them less specific and more superficial. Others oppose making the courses more technically specific on the score that necessarily the effect must be to narrow them. I venture to maintain that the change I recommend would broaden the instruction and also make it more thorough and more specifically adapted to the needs of the engineer-student. To reach this result the selection of matter for elimination must be made with the utmost care, keeping constantly in view the work for which the engineer-student is being specifically trained, and that we are not only giving him knowledge, but we are training him to think straight, and that it will remain for him to acquire in the school of experience that additional training in application which cannot be obtained elsewhere.

EQUIPPING CARS WITH ELECTRICAL APPARATUS

H. I. EMANUEL

WHILE the equipping of cars with motors and control apparatus may appear to be comparatively simple work, there are a number of details and methods of installing that are probably unfamiliar except to those who have been engaged for several years in this line of work. Points which may appear self-evident are often overlooked and afterwards prove to be a source of vexing troubles. The grades and types of apparatus change from year to year and the requirements grow more exacting. The little single truck cars with their motors of less than 25 hp have given way to larger and heavier cars of ever increasing size and weight. Interurban cars with coach, smoker and baggage compartments provided with modern conveniences of buffet, toilets, ice-cooler, etc., and having a total weight of 100 000 pounds; equipped with heavy motors and trucks capable of making 70 miles per hour and sometimes making round trips of 250 miles, are an actual reality of to-day. While all this has taken place, the amount of work and abuse the motors can and do stand with little or no care has been increased. By the use of the multiple control system the large currents required by heavy cars can be handled and the cars can be coupled together electrically so that each will perform its share of the work and the cars can be accelerated automatically.

When the car body, trucks and electrical equipment have been brought together from the various places of manufacture there still remains an important step in the construction of the car which has a considerable bearing on its future reliability, and that is the installation of the apparatus. No matter how well the individual pieces have been constructed, if the proper attention is not given to the installation of the apparatus, the reliability of the whole car is liable to be impaired. As a general rule it may be said that no provision is made for installing the electrical apparatus while a car is being constructed. The airbrake cylinders, levers and rods have pretty definite positions and little change can be made in their location, and hence electrical wires and apparatus usually have to take whatever space is left. To get the best results, each piece of apparatus should be placed with a view to its future maintenance and accessibility. It should be in close proximity to any apparatus with which it is connected by any considerable amount of wire in order to keep down th cost of material and installing. Freedom from wheel wash, clearance of trucks and balancing of the car body should all be given attention in laying out the general arrangement, as the space availabl under the car is usually limited and there are objections to be foun to any arrangement selected.

PLACING THE APPARATUS

The apparatus should be so placed that the two sides of the ca body carry approximately equal weights. If the car is out of ba ance, some of the apparatus may be moved from the heavy side neare to the center or from the light side further away from the cente The distance between a perpendicular line through the center of gra ity of the piece of apparatus and a line drawn through the center c the car between the two king pins multiplied by the weight of th apparatus is the true value of weight that should be credited to th side of the car, i. e., 200 pounds at a distance of one foot from th center line and 100 pounds two feet from the center line have equ value. If proper consideration is not given to balancing it will prol ably be found that the car will list to one side after it has been ope ated for some time. If the sum of the products of weight times di tance are approximately within ten per cent of each other the c springs will take care of the discrepancy.

CLEARANCE AROUND TRUCKS

A space should be left around the trucks to allow the truck to r volve around the smallest radius curve the system may have. Tl amount of space required for this may be determined by measurin upon the truck the horizontal distance from its center bearing to tl corner of the truck or to any other point of greater horizontal di tance, should there be such. This distance used as a radius with tl kink pin as a center can then be laid off on the car body. No wirin or piping should be placed between the car body and the wheels, the body will be nearer the wheels when loaded than when light. the car body is on the trucks the distance that the elliptical spring open plus about one inch additional allowance for closing the spir spring, will give the clearance required above the wheels. If the c body is not on the trucks the clearance can be ascertained by ut izing, in addition, measurements that can be obtained through the si bearings.

WIRING UP MOTOR LEADS

The motor leads are sometimes a source of a great deal of trouble. Often they are left hanging loose in a long twisted snarl where they can catch on the motor cover, latches, wheels or other projections as the car passes around curves. Thus the insulation is constantly being rubbed and numerous short-circuits, delays to the car and expenses for repairs result. Motor leads can be put up so that they will be as free from trouble as any other portion of the car wiring. The leads should be brought from the point where they emerge from the motor case to the flat surface on top of the motor and secured on this surface by a hardwood cleat about twelve inches long which is fastened to the motor case by two tap bolts. In passing through this cleat the leads should be spaced about one and one-half to two inches apart and pass up to the car body in the shape of a "U" or "S," leaving the necessary slack required for the turning of the truck. The motor leads should be secured to the car body by a similar wood cleat and then should come the usual clasp connector. This leaves only the extra flexible wire, of which the motor leads are made, to be affected by the car movement. If the cleat is not placed on the car body between the clasp connector and the motor, the soldered wire at the connector is liable to break. The nearer the cleats are brought to the king pin both on the car body and the motor, the less will be their relative movement and the amount of slack wire required.

WIRING UP LIGHTS, ETC.

The lights, switches and heaters are some of the principal contributors to the origin of a large proportion of fires which occur. Flexible wire only should be used in these circuits and splicing should be avoided as far as possible. The fastening of wire at two points, with slack between so that it may vibrate with the motion of the car, should be avoided. Some roads have gone so far as to solder the wires into place in the lamp sockets after they have been secured by the screws.

The head-light resistance should be especially looked after, for if the head-light carbons get together and fail to pick up the increased current flowing will result in considerable heat arising from this resistance.

Small switches which are not mechanically strong should be avoided. An improperly operating contact on a snap switch is liable to hold an arc when turned off. Placing fuses and switches in a fireproof cabinet reduces the risk of fire and usually simplifies the wiring.

INSTALLING RHEOSTATS

Rheostats should be placed so that there is considerable free air space above them and so that the heat arising from them can be easily dissipated. The use of asbestos or other fire-proofing on the car bottom above the rheostats affords excellent protection. The jumpers between the rheostats and the wires leading to the rheostats can with advantage have their insulation removed. This obviates the chance of heat from the rheostats or an imperfect contact at the terminals setting the insulation on fire and transmitting it to the car body.

Neat and well constructed work has the advantage not only in appearance, but it is well worth while on account of the reliability which goes with it. Vice versa poor looking work is seldom either reliable or economical.

TESTING LARGE MOTORS, GENERATORS AND MOTOR-GENEATOR SETS—IV

RAILWAY CAR AND LOCOMOTIVE EQUIPMENTS

H. L. BEACH

THE ideal testing outfit for exhaustive tests on railway car equipment would consist of a number of miles of track having grades and curves of various kinds, trolley wires and third rails supplied with both alternating and direct current and several cars, varying in size and weight, so that all kinds of service encountered in actual practice could be reproduced. An equipment of this kind would, however, be impracticable. Each variation in equipment to be tested might require an additional car or locomotive, the parts would have to be arranged with the proper gears and pinions, the proper section of the test track would have to be cleared of all traffic, to allow a continuous and uninterrupted test and then a motorman would have to reproduce over and over again the predetermined conditions of the test in their proper sequence and time. Even if the expense of such an equipment was not prohibitive it would hardly be possible to lay out a track which would reproduce all the probable required variations in grade and curvature.

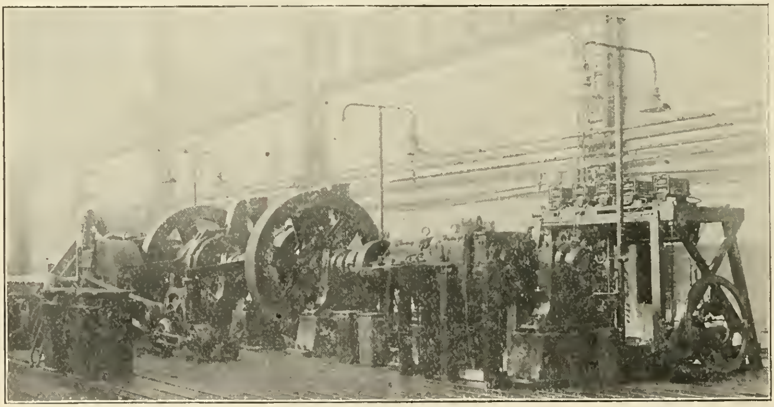

FIG. I—GENERAL VIEW OF FLY-WHEEL TEST

THE APPARATUS

An equipment has been designed and constructed at the works of the Electric company to produce results equivalent to those that

would be obtained if the equipment was actually run over the tra
on which it was planned to be used. A general view of this te
outfit, known as the "fly-wheel test," is shown in Fig. 1. It consis
essentially of a long shaft with two heavy fly-wheels mounted ther
on. The shaft is divided into four sections which may be connect
together by flange couplings. All the sections are supported
bearings, the end sections being of such a length as to accommoda
two large railway motors between the bearings. The two midd
sections of shaft carry fly-wheels which have large prony brak
fastened securely to them.

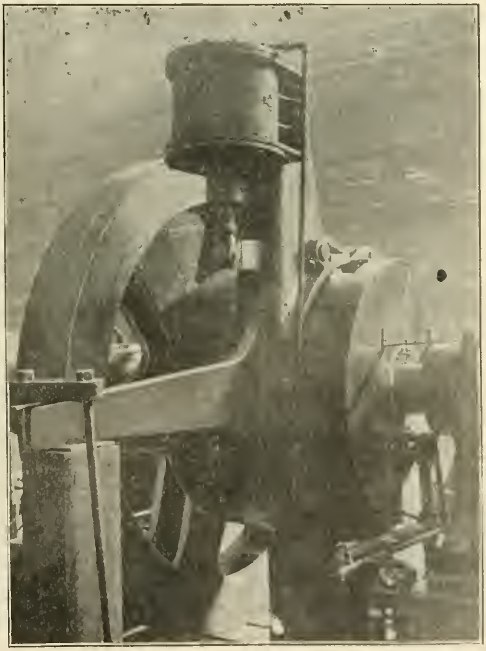

FIG. 2—DETAIL VIEW OF ONE FLY-WHEEL AND PRONY BRAKE

The work done by a motor in starting a car or locomotive m
be divided into two parts, that used in overcoming friction and th
used to overcome inertia. The desired equivalent friction load
obtained in the bearings of the outfit. If the test requires a great
friction load than that obtainable in the bearings, the additional lo
is easily obtained by the use of the prony brakes which are of t
ordinary type, but of very large capacity and controlled by co
pressed air as shown in Fig. 2. The brake drum is kept from ove

heating by the usual method of supplying water to its inner periphery.

The inertia of a car is a quantity depending upon its weight and rate of acceleration. Since the direction of acceleration is not a modifying feature the desired inertia may be supplied by large masses moving in circular paths and this is furnished by the fly-wheels. The inertia effect of any car within practical limits may be obtained by varying the rate of acceleration which is done by a proper selection of gears and pinions and by the use of the brakes.

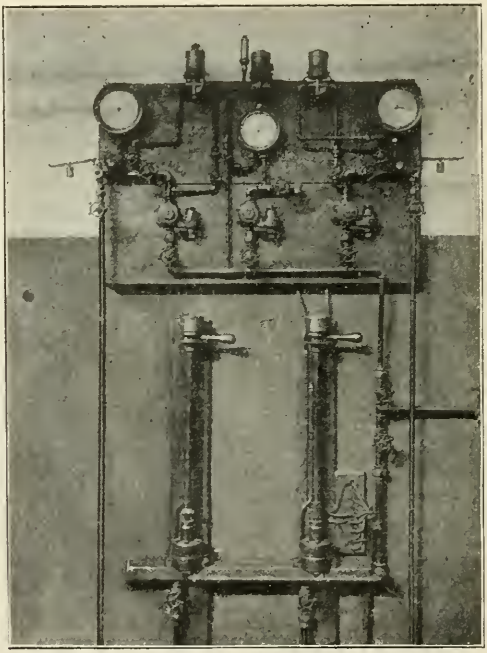

FIG. 3—AIR BRAKE CONTROL BOARD

If the motors are large, both brakes and fly-wheels may be required. If the motors are small, one wheel is usually sufficient. Four motors may be tested at once by putting two on each of the end sections of the shaft.

The electrical control of the motors can be obtained in almost any manner desired. A hand controller such as is used on small street cars may be used or the motors connected as in an ordinary laboratory test using knife switches and a rheostat, or the unit switch control may be used. The last named method is the one ordinarily used and is by far the most satisfactory as the operation of the individual switches can be controlled from a distance and the circuits to be manipulated by hand or by the auxiliary control apparatus are very small and thus easily handled. Any kind of resistance may be used, but it is found that the grid type of railway diverter as shown on top of the wooden supporting frame in Fig. 1 is most satisfactory.

The control of the brakes is obtained through an air control board, as shown in Fig. 3. This board contains valves, connections and pressure gauges arranged so that either brake may be operated alone or they may be operated together. The air supply may be controlled by hand or through the operation of electro-magnetic valves. The pressure on the brakes may be varied so that one brake will have a continuous pressure of a certain desired amount, while the other brake pressure may be anything desired. Low pressure on the brakes is obtained through reducing valves and relief valves, so that the reservoir pressure may be reduced to the pressure desired for the brake. By referring to Fig. 3 the arrangement of this apparatus may be readily seen. The three magnet valves are at the top with an air whistle connected to the center one. The relief valves are mounted at either end of the board with levers and weights and the reducing valves are mounted in a row near the bottom of the board. Two standard motorman's brake valves below the board are connected one to each brake.

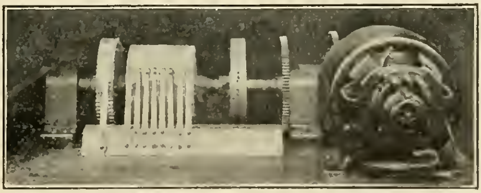

FIG. 4—CONTROLLING MECHANISM

The control of the electro-pneumatic unit switches may be obtained through the operation of a master controller or through the operation of a small commutating switch as in Fig. 4. This commutating switch consists of a drum of insulating material about six inches in diameter, mounted on a shaft and geared to a small direct-current motor. Stationary contact fingers insulated from each other bear on the surface of this drum. Connections between the fingers are obtained by mounting contact plates on the surface of the drum. Any desired combination of connections between the contact fingers may be laid out on the drum so that the connections will be made in regular sequence when the drum is revolved. The time of revolution of the drum may be regulated by resistance in the driving motor circuit and when the speed is adjusted, the desired sequence of connections may be repeated with absolute regularity for any length of time. This is important as it eliminates entirely the personal factor in testing due to the manual operation of the switches and insures absolutely uniform results. Once set the apparatus will run indefinitely with no attention other than a general oversight of bearings, brakes and motors to see that the apparatus is kept in good running order and is not overheating.

METHOD OF TESTING

The test equivalent to the run a motor will be required to perform in actual service is obtained in the following manner. Speed time curves are plotted of the run a car will make over the road on which the motor is to be used. These curves are then averaged and a typical run curve is plotted, which represents the average energy the motor must produce in starting the car, accelerating it to a given speed, cutting off the current and letting it coast for a certain time, applying the brakes, stopping the car and allowing it to stand for a given time. This run repeated for the length of time the car is to run, will make the same demand on the motor as the actual run of the car. A set of typical run curves as above described is shown in Fig. 5. Three curves are shown, one of amperes, another of volts and a third of miles per hour, all plotted with respect to time in seconds. An examination of these curves will show that in this case the car is started and brought to full speed in twenty seconds, that is, all the resistance is cut out in twenty seconds. The car then runs nine and one-half seconds when the power is shut off and it is allowed to coast. The brakes are then applied and the car is stopped so that the total running time will be fifty-seven and one-half seconds. A stop of twenty seconds is allowed and the run is then repeated.

This result as accomplished on the fly-wheel test is obtained in the following manner:

First, calculations are made to determine the number and value of the steps necessary in the grid diverters to keep the accelerating current at approximately 192 amperes as shown on the curve of amperes. The connections are then made to the motors by unit switches there being as many circuits as there are steps in the resistance plus one to close the main circuit. This done, the next thing is to regulate the speed of the small motor shown in Fig. 4, so that the drum will make one revolution in seventy-seven and one-half seconds, this being the length of time for one run. On the supposition that there are five steps of resistance, contacts will be laid out on the drum equally distant apart, and arranged so that the battery connections are made to the unit swiches, one at a time four seconds apart, thus cutting out all the resistance in twenty seconds. These contact plates on the drum will be arranged so that contact will be broken when the drum has moved for twenty-nine and one-half seconds. There will then be a blank space in the drum until the point is reached when it is necessary to put on the brakes. At this point contacts will be made on the drum which will connect the battery to one of the valve magnets, shown in Fig. 3, thus putting the air pressure on the brakes and stopping the motors. The air pressure on the brakes is regulated by trial to such a value that the motor will be stopped exactly fifty-seven and one-half seconds from the time it started and the contacts on the drum may be cut off at this point so that the brakes will be off before it is time to start the run again. A sketch of the development of the drum for such a set of

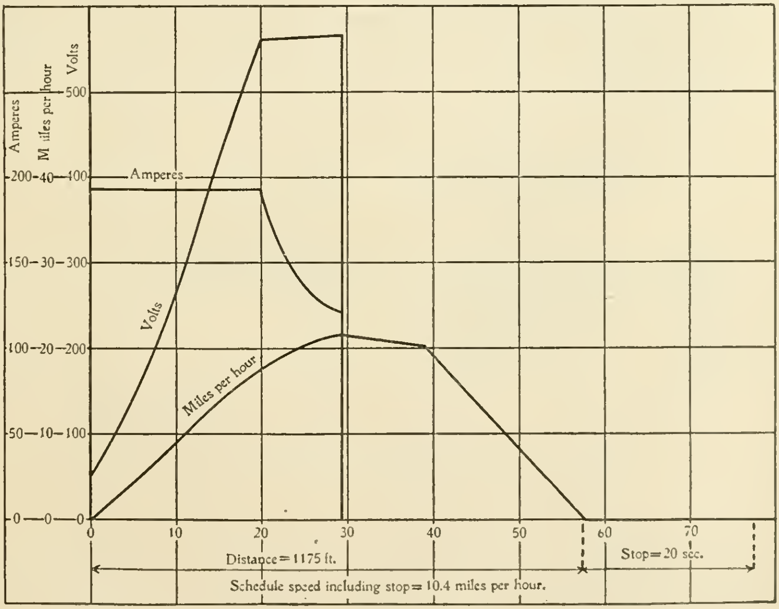

FIG. 5—TYPICAL RUN CURVES

conditions as above described is shown in Fig. 6. One terminal of each of the valve magnets of the unit switches is connected to the negative side of a battery and the positive side is brought to the finger lettered *B+* on the sketch. Wires to the other terminals of the valve magnets of the various switches are lettered *1, 2, 3, 4, 5* and *6* and the wire to the brake magnet is lettered *B*. A simple diagram of this scheme of connections is shown in the upper part of Fig. 6. The distance of 1175 feet called for on the curve, being the distance the car would run on this typical run, is obtained by noting the number of revolutions the motors would have to make if they were mounted on a car and geared to the axles. The equivalent number of revolutions of the shaft is then ascertained and is obtained by increasing or decreasing the load of the motors. By the proper manipulation of the two brakes and fly-wheels the load may be adjusted so that it is equivalent in its effect on the motor to the load as obtained with any sized car in actual railway service.

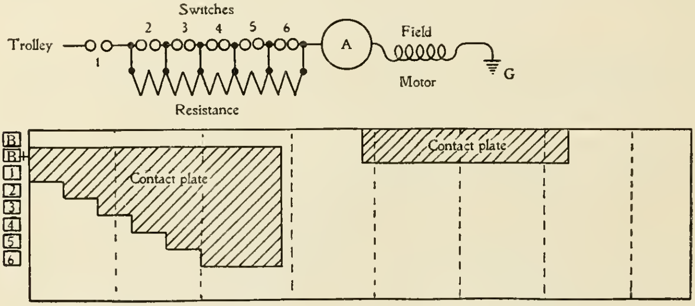

FIG. 6—SCHEMATIC DIAGRAM OF CONNECTIONS AND DEVELOPMENT OF CONTROL DRUM

Dotted lines represent ten second intervals.

Another method of making this same test is by using a standard multiple unit car equipment of any type. The accelerating current of the proper value is obtained through the regulation of the grid diverters and the limit switches used with the equipment. The speed of cutting out this resistance is regulated by the load on the motors, which is regulated as before described by the manipulation of the brakes and fly-wheels. In this case the master controller of the equipment would be fastened in the full running position and the positive battery connection to the master controller would be run through the drum of the commutating switch shown in Fig. 4. When running in this way only three contact fingers are required.

The contacts on the drum would consist of two strips, one to make contact between the positive side of the battery and the master controller wire for a distance on the drum equivalent to twenty-nine and one-half seconds movement and the other as before for the brake magnet.

The control in the last described case will of course handle the motors in series parallel combinations and it will be necessary to have two or four motors according to the equipment to be used on the car, but by using the series parallel bridging system, as described in a previous article in the JOURNAL*, it will be seen that the value of the accelerating current on the motors is the same in series and in parallel and is not interrupted at the point of transition so that the actual effect on the motors is the same as when operating one motor alone.

The test of control apparatus is obtained in the same way as the test of motors, the only difference being that the effect of the run is noted on the control apparatus instead of on the motor and the ability of control apparatus to withstand the operation of a certain sized motor is easily ascertained by connecting the two kinds of apparatus together on the testing outfit and making a typical run as above described, taking temperatures on the control to see that the heating is not excessive.

The graduation of the various steps in the grid diverter, to be supplied with a car equipment may be easily checked, to determine the correctness of the calculations, with this outfit by placing an ammeter in the circuit leading to one of the motors and noting the fluctuations in current. These fluctuations should be the same as each step of the diverter is cut out so as to keep the acceleration of the car at a constant value until all the resistance is cut out of the motor circuit and the motors are running on full voltage.

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*See *The Electric Journal*, Vol. III., p. 127, April, 1906.

EXPERIENCE ON THE ROAD

PRESSING ON ARMATURES

S. L. SINCLAIR

THE pressing of armatures on engine shafts forms an important part of the work of an erecting engineer. Important as the subject is the writer has seen but little data bearing upon the subject. This may be because the work is of such a character as to require long experience to secure known and satisfactory results and because each "fit" may have different proportions and characteristics. One or two thousandths of an inch may make but little difference in the shop, where every facility is at hand for this class of work, yet on the road a miscalculation to that extent may cause much trouble and delay, if one has to use, for instance, a much used bolt with poor threads and a wrench with jaws several sizes too large, requiring blocking, and in addition to this being too light for the work.

The writer recalls one case, and the only case where he had to take off an armature before it was pressed "home." In this instance the armature had been pressed to within one and one-half inches of its proper position when the wrench broke. Another could not be secured until the following day. Having then a satisfactory wrench the bolt was not sufficiently strong to start the armature after standing several hours and an hydraulic ram had to be secured to complete the job. In some cases the "actual" difference in diameter for fit may be found to be excessive. This can best be overcome by enlarging the armature bore. Time expended on filing or scraping is profitable in comparison with the time that may be lost if one takes chances on the fit, resulting frequently in the armature sticking, consequent withdrawal and finally filing, as should have been done in the first place. The writer has filed many hours in hot engine rooms in preference to having too tight a fit with its uncertain results. A key out of line and other unknown obstacles frequently upset one's calculations and an armature will go on harder than was expected. In an extreme case of this kind the use of hot irons placed about the armature hub will expand it sufficiently to allow the armature to be pressed home, which could not otherwise be done without a heavier bolt or rods as the case may require. If heat is used great care should be taken to prevent overheating the armature winding.

For pressing on the armatures of small units, say up to 200 kw, a single bolt is preferable to two side bolts. The bolt is screwed into the end of the shaft, as shown in Fig. 1. After placing the armature on the shaft as far as it will go without pressure, a piece of pipe, slightly larger than the shaft diameter, is placed over the bolt and shaft and against the armature core. At the outer end of the pipe is placed a large washer or strong block, against which the nut presses. The bolt and pipe should be of sufficient length to allow the armature to be pressed on all the way without change of pipe, etc., thereby saving much time.

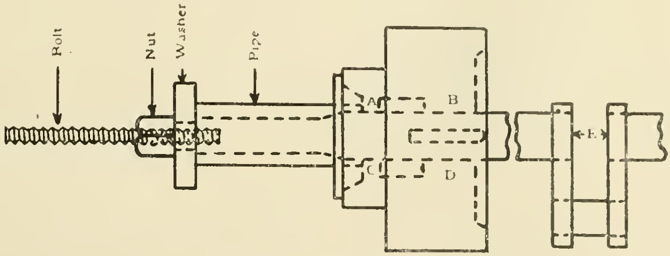

FIG. 1

Another device for attaining similar results is a combined screw and hydraulic jack which can readily be secured to the end of the shaft. The single bolt is especially desirable when pressing armatures on shafts of center-crank engines, as blocking the crank at *E*, Fig. 1, is an uncertain guard against straining it with side bolts, when it is necessary to pull on the far end of the shaft.

To summarize the matter briefly, use for taking measurements a reliable outside caliper, an inside micrometer caliper and allow sufficient time to measure the entire surface carefully. Fit the key to the armature keyway. Secure reliable bolts and wrenches and get everything required together before starting to press on the armature. Cover the shaft and bore of the armature with white lead and oil, which is the best lubricant for the purpose, and after starting keep the armature moving until it is all the way on.

TECHNICAL EDUCATION.

A Letter by Frank J. Sprague.

One of the apprentices in the works of the Electric Company recently requested permission to publish a personal letter from Mr. Sprague written several years ago, which had been instrumental in directing his career.

A part of the letter from the apprentice reads as follows:

"Since I have been here I have run across several young men who have differed with me in regard to the value of a technical education. Not a few of these have had the choice from their parents of either going to college or going to work. What I might call their lack of foresight or inability to understand exactly what they were 'up against,' has prompted them to choose the latter course, because of its immediate returns. I believe that a little advice from men of standing would turn such young men to the former course for their own good. The wide distribution of such sentiments as are expressed in your letter is what is needed, and it is my purpose in writing to ask your permission to publish your letter in The Electric Journal."

Mr. Sprague says in his reply: "I feel quite as strong now as formerly that a thorough technical training is almost invariably vital to any future success in the general electrical field, and if, as you suggest, the publication of the letter can do any good, you are entirely at liberty to use it."

The original letter of Mr. Sprague reads as follows:

"On account of the rapid growth of electrical industries and the variety of departments, it is but natural to think that in that profession a young man will have a greater opportunity of success, or at least of reasonable livelihood, than in other walks of life which may seem less crowded.

"I think, however, that unless a boy has distinctive mechanical, as well as electrical tastes and natural equipment, success is not much more likely in the electrical than in any other field. But, in any case, if one is to rise above the ordinary level, it is now I think essential that he shall have a thorough groundwork of technical education.

"This was not so essential in the earlier days, and especially if one had any marked talent, but the electrical profession is now being reinforced everywhere by young men who have had all the advantages obtained in the best schools here and abroad, many of whom enter into practical work in manufacturing establishments, or into construction work.

"A boy who starts from a high school and goes into an electrical establishment is heavily handicapped; he has not that class of electrical knowledge which will make him of any value in designing and testing electrical apparatus, hence he is almost always driven to ordinary machine electrical work, which will offer no more than moderate pay and livelihood.

"I would especially advise that the boy make every effort to get such education as is provided by Cornell, Stevens, or the Massachusetts Institute of Technology. It may be hard work, and the getting of that education attended by sacrifice and lack of luxuries, but there is no time in his life when he can better make that fight and when probably he will have less responsibility as to others than now.

"I have seen so many good men, who, a few years ago, were quite on a par in all ordinary electrical matters with others, gradually settle back solely because they did not have a technical education, that now, when it is so vital, and when every young man who goes into this work has to compete with men who are trained, I look with a great deal of reluctance upon seeing a boy start at one of the electrical manufacturing companies instead of where he can get, what he cannot get later, a proper groundwork for his success."

CONTRIBUTORS TO THE JOURNAL FOR 1906

During the past year nearly one hundred names appeared on the author list of the Journal. In addition to the articles written expressly for the Journal, several which have been presented elsewhere have been reprinted, in some cases with special revision by the authors.

The list of the contributors for the year with some notes regarding them and their work will be of interest to the readers of the Journal.

A considerable proportion of the contributors are members of the Electric Club, by which the Journal is published. In general, the contributors are members of the Club, and are connected with the Westinghouse Electric & Manufacturing Company unless otherwise noted.

C. L. ABBOTT was with the Short Electric Railway Company for five years and the Walker Electric Company, of Cleveland, for five years. He has been with the Electric Company since 1899 and is now district engineer for New England.

E. G. ACHESON, discoverer and inventor of carborundum, organizer of the Carborundum Company, the International Acheson Graphite Company, the Siloxicon Articles Company, president The Acheson Company, Niagara Falls.

H. B. ALVERSON, superintendent The Cataract Power & Conduit Company, Buffalo, N. Y.

H. C. AYRES, manager and superintendent of the Greenville (Ohio) Electrict Light & Power Company.

C. W. BAKER (Queen's Univ., '05) commenced the Electric Company's apprenticeship course in 1905 and is still on the course. He is paying especial attention to meters and relays.

H. S. BAKER (Queen's Univ., '02) took the apprenticeship course at the Electric Company's works, after which he entered the engineering department. Since last May he has been with the Ontario Power Company.

J. M. BARR, (Univ. of Wisconsin, '94), after graduation, studied abroad for a year and then took a three years' apprenticeship in a large railway shop, after which he took the Electric Company's apprenticeship course. He has been connected with the testing and engineering departments and was for some time assistant to the manager of industrial and power division. Recently he has been transferred to the manager of works office.

W. BARNES, JR., crane inspector, the Electric Company, has been connected with the testing and works operating departments for several years, and at present has general charge of a large number of electric cranes and elevators of various sizes.

H. L. BEACH (Ohio State Univ., '04) entered the apprenticeship course of the Electric Company in the summer of 1904. Since July, 1905, he has been connected with the railway engineering department, where he is specializing on the design of multiple-unit control equipments.

J. R. BIBBINS (Univ. of Mich., '99), after three months' general draughting work with the Detroit Edison Company, was for six months operating electrician for the public lighting commission of Detroit. He then spent fourteen months on general engineering work on power station development with the Detroit Edison Company. For one year he was assistant electrical engineer of the Detroit United Railways. Since 1902 he has been technical writer for the Westinghouse Machine Company, his work embracing the examination and reporting of power plant work and developments in power plant machinery.

WILLIAM BRADSHAW (Western Univ. of Pa., '97) was electrician at the Schoenberger Steel Company for two years and later was with the Schoen Pressed Steel Company. Since 1899 he has been in the engineering department of the Electric Company, where he has become an expert in the designing and testing of electrical measuring instruments.

B. H. BRANCH (Johns Hopkins, '95, Baltimore Polytechnic Institute) entered the employ of the General Electric Company in the testing department, and has since held various positions with the company and has gone to the assistance of the Edison Company, of York, Pa., and the Consolidated Gas, Electric Light and Power Company, of Baltimore. At present he is an engineer at the Philadelphia office of the General Electric Company.

FRANK CONRAD, engineer, detail and supply division, the Electric Company. When a boy he was employed in the arc lamp department; he was later engaged in testing lamps, meters, controllers and other detail apparatus. Much of the apparatus now in use has been designed and invented by him.

C. S. COOK (Worcester Polytechnic Institute, '85) entered the Electric Company in 1887 as an engineer. He constructed and operated a number of plants, made a specialty of the application of motors to industrial service, especially that in steel mills; has been an engineering salesman and manager of the Pittsburg office, and is now the head of the railway and lighting division of the sales department.

WILLIAM COOPER attended Cornell University, where he was in the class of 1887. Subsequently he was for three years chief engineer and master mechanic of the Twin City Rapid Transit Company; in the railway engineering department of the General Electric Company for three years; chief engineer and superintendent of the Bullock Electric Mfg. Company for six years. At present he is in charge of the control section of the railway engineering department of the Electric Company.

A. W. COPLEY (Univ. of Kansas, '03) took the apprenticeship course and has since given especial attention to the testing and calibration of standard instruments and to various particular problems, especially those involving alternating currents.

O. H. CROSSEN. The contribution by Mr. Crossen describes certain work which he did when in charge of a substation in the West. He is at present in section "C" of the works of the Electric Company.

W. M. DANN (Ohio State Univ., '02) took the apprenticeship course with the Electric Company and is now in the transformer engineering department.

J. N. DODD (Princeton, '93) was in the engineering department of the Walker Company, of Cleveland, for two and one-half years. For five and one-half years he was electrical engineer for Dick, Kerr & Company, of London. Since 1905 he has been with the Electric Company as engineer on direct-current design.

C. R. DOOLEY (Purdue, '00 and '02), president of the Casino Technical Night School, started with the Electric Company in the dynamo test about four years ago. For about two years he has been engaged in engineering work in connection with rotary converters and turbo-generators. He assisted in the editorial work of THE ELECTRIC JOURNAL for about a year.

C. E. DOWNTON (Purdue, '91) was with the South Covington & Cincinnati Street Railway Company and World's Columbian Exposition Company; entered the Electric Company in 1895 as a student. He was foreman of the dynamo test until 1902, when he was appointed to his present position of foreman of apprentices.

C. B. DUDLEY (Yale, '71 and '74), chemist, the Pennsylvania Railroad, president for a number of years of the American Society for Testing Materials.

HAYDEN EAMES (U. S. Naval Academy, '82) was for some time a specialist in ordinance work. He has successively been general manager of the Columbia Bicycle Company; organizer and general manager of the Pope Seamless Tube Company; organizer and general manager of the Electric Vehicle Company, and manager of the vehicle motor department of the Electric Company. At present he is sales agent for parts of electric and gasoline-driven vehicles at Cleveland, Ohio.

CHARLES WILLIAM ELIOT, president, Harvard University.

H. I. EMANUEL has been with the Electric Company since 1903 and has followed railway work particularly, being in Brooklyn for some time as an assistant in installing multiple control equipment. He installed the multiple control equipment on the Lackawanna & Wyoming Valley Railway Company, and is at present in charge of the installation of multiple control equipments for the Electric Company at the works of the Cincinnati Car Company.

C. J. FAY (Case, '03) took the apprenticeship course. Later he was made assistant foreman of dynamo test and was for some time in charge of working up tests. At present he is in charge of induction motor testing

H. W. FISHER (Cornell, '88) was for a short time assistant engineer of Bergman & Company, and was also with the C. & C. Electric Company. He was for three years with the Central District Printing & Telegraph Company, of Pittsburg. Since 1889 he has been with the Standard Underground Cable Company, of which he is now chief engineer.

H. GILLIAM entered the employ of the Electric Company in 1897 and a year later was transferred to the erecting department on general work. For three years he was district engineer at Philadelphia and for a year and a half district engineer at St. Louis. He was district engineer at New York until 1906, when he was appointed superintendent of erection.

DEAN HARVEY (Armour Institute of Technology, '00) was for five years engineer with the Underwriters' Laboratories at Chicago. For two years after entering the Electric Company's employ he was engineer on switches, fuses and insulation. His present position is insulation engineer.

S. Q. HAYES (Georgetown Univ., '92, Johns Hopkins, '94) entered the employ of the Electric Company in 1894 as a student, was a draughtsman for six months and for the last nine years has been in the switchboard division of the engineering department. He is now switchboard engineer in charge of estimates and project work.

G. T. HEDRICK entered the employ of the Electric Company in 1893; spent five years in the shop and then entered the erecting department, where he has had a large experience on multiple control work. At present he has charge of work on the single-phase system of the Vallejo, Benicia & Napa Valley Railway.

R. H. HENDERSON (Northwestern Univ.) spent several years in factory and central station work in the Middle West, after which he became connected with the detail engineering department of the Electric Company and was for a number of years assistant superintendent of the Newark works. His present position is with the Sawyer-Mann Electric Company.

E. M. HERR, after graduating from Yale, took an apprenticeship in railway shops. He has been connected with the Chicago, Milwaukee & St. Paul; the Chicago & Northwestern, the Burlington, and was superintendent of motive power on the Northern Pacific. He has also been general manager of the Gibbs Electric Company. About eight years ago he came to the Westinghouse Air Brake Company, of which he has been vice president and general manager. For the last year and a half he has been first vice president of the Electric Company.

J. M. HIPPLE (Ohio State Univ., '98) has been with the Electric Company since 1898. After spending some time in the shop and testing department, he entered the engineering department and is now section engineer on direct-current apparatus in the industrial division. Mr. Hipple has recently been engaged in the development of auxiliary-pole variable speed motors.

L. F. HOWARD (Mass. Inst. of Technology, '95) was employed in the U. S. Light-house department until 1889, when he took up power station work in the electrical engineering office of the Boston Elevated Railroad. Later he was transferred to the signal department, where he remained until 1905, when he accepted his present position as electrical engineer with the Union Switch & Signal Company.

J. B. INGERSOLL entered the employ of the Electric Company in 1894 and spent about five years in the testing department, when he was transferred to the erecting department. He was with the Montreal Street Railway for about a year in charge of their operating department and is at present assistant general manager and chief engineer for the Spokane & Inland Railway Company.

R. P. JACKSON (Univ. of Mich., '02) was a draftsman with the Western Electric Company, Chicago, and later took the apprenticeship course in the Electric Company. He was for some time engaged in the railway engineering office in the development of single-phase railway control equipment and recently has been appointed engineer in charge of protective apparatus.

H. D. JAMES (Univ. of Pa., '95 and '96) entered the employ of the Cutler Electric Company and afterwards went to the Philadelphia Engineering Company. Later he was connected with the Otis Elevator Company's engineering department part of the time as their division engineer in charge of the Pittsburg district. He entered the employ of the Electric Company in 1903 and is now engineer in charge of industrial controller design.

J. E. JOHNSTON was for some time engaged in installing power plant machinery for the Electric Company in the far west. He is at present an erecting engineer in the St. Louis district.

A. C. JORDAN (Univ. of Maine, '04) took the Electric Company's apprenticeship course and is now a salesman in the Pittsburg district. Mr. Jordan has specialized on railway motor work.

P. O. KEILHOLTZ (U. S. Naval Academy, '84; Johns Hopkins, '86) has specialized on the design and operation of power and lighting plants. His present position is consulting engineer of the Consolidated Gas, Electric Light & Power Company, of Baltimore.

W. C. KERR (Cornell, '79) was an assistant professor at Cornell from 1880 to 1883. Since then he has been with the Westinghouse companies. At present he is president of Westinghouse, Church, Kerr & Company, and first vice president of the Westinghouse Machine Company. He is also a trustee of Cornell University.

A. KINGSBURY (Ohio State Univ. and Cornell, '89) was instructor and later professor in mechanical engineering at New Hampshire University; mechanical engineer for the H. B. Camp Company; professor of applied mechanics, Worcester Polytechnic Institute, 1899 to 1903. Since 1903 he has been mechanical engineer in the power division of the engineering department of the Electric Company.

S. M. KINTNER (Purdue, '94) was for a number of years on the faculty of the Western University of Pennsylvania as professor of electrical engineering. On coming to the Electric Company he entered the engineering department, where he has been engaged in research work. He is at present engaged in developing single-phase railway motors.

H. L. KIRKER (Ohio State Univ., '89) was for a number of years with the Electric Company, after which he went abroad and was an engineer with the French Westinghouse Company at Havre. Later he was in charge of the electrification of the London Metropolitan Railway and of the Mersey tunnel. At present he has in charge the electric installation at the Sarnia tunnel.

B. G. LAMME (Ohio State Univ., '88) was in charge of the mill department of the Philadelphia Company; entered the Electric Company in 1889; was caretaker of the duration test of incandescent lamps; later was connected with the testing department, and developed improvements in arc lighting apparatus; he proposed and developed various new forms of apparatus and has been the chief designer of the Electric Company; he was made assistant chief engineer and is now chief engineer, at the head of the engineering department.

W. F. LAMME (Cornell) entered the student course of the Electric Company; was engaged in experimental and testing work; was connected with the exhibit at the Paris Exposition; has been erection engineer, and is now district engineer of the San Francisco office.

P. M. LINCOLN (Ohio State Univ., '92) was for two and one-half years with the Electric Company on testing work. He then went to Niagara Falls and was for seven years electrical superintendent of the Niagara Falls Power Company, where he supervised much of the early engineering work done by that company. On his return to the Electric Company he took up engineering work in connection with power transmissions. Since 1904 he has held his present position as head of the power division of the engineering department.

O. S. LYFORD, JR. (Yale, '90) took a post-graduate course at Cornell in 1890-91, after which he successively filled the following positions: Chief engineer and superintendent of Siemens & Halske Electric Company, 1895-1897; chief engineer of the Electric Company, 1897-1899; vice president and general manager Siemens & Halske Electric Company, 1899-1900. Since 1900 he has filled his present position of chief electrical engineer of Westinghouse, Church, Kerr & Company.

T. D. LYNCH (W. Va. Univ., '91) was with the civil engineering firm of G. W. G. Ferris & Company from 1891 to 1896 in shop and mill inspection, erection and supervision and for two and one-half years was western manager in charge of their Chicago office. From

1897 to 1899 he was an assistant inspector in the bureau of steam engineering, U. S. Navy. Since 1900 he has been with the Electric Company in the capacities of inspector of materials and engineer of process section in the research division of the engineering department, which latter position he now holds.

PAUL MacGAHAN (Columbia, '96) was born in France, where his father was an American war correspondent. He entered the employ of the Electric Company in 1896, and after two years' shop work, went into the work of developing new lines of instruments which, at that time, comprised only the Shallenberger and type C indicating meters. At first he acted as assistant to Mr. Frank Conrad. He is now engineer in charge of instrument and relay work.

A. M. MATTICE (U. S. Naval Academy, '84). From 1879 to 1883 he was an instructor in engineering at the Naval Academy. In 1887 he was assistant engineer in chief of the navy. From 1889 to 1900 he was chief assistant of E. D. Leavitt, of Boston. In 1900 he became chief engineer of the Electric Company, and in 1903 chief engineer of the Westinghouse Machine Company. In 1904 he went to the Allis-Chambers Company as their chief engineer. More recently he has been engaged as general consulting engineering in New York City.

E. S. McCLELLAND has filled the position of assistant chief engineer of the Westinghouse Machine Company ever since that office was created about four years ago. Previous to that he was for a number of years chief draftsman. Mr. McClelland began work with the company before the drafting department was divided up into gas engine, turbine, producer and other divisions and has thus acquired a broad knowledge of the company's various products.

W. G. McCONNON (Iowa State College) entered the employ of the Electric Company in 1894. He has had charge of installations at the Third Avenue Railway Company, New York, and the large high-tension installation for the Missouri River Power Company. He was district engineer at Baltimore for several years. At present he is installing the single-phase system of the Spokane & Inland Railway.

W. M. McFARLAND (U. S. Naval Academy, '79) was a specialist in marine engineering for a number of years. He was assistant professor of mechanical engineering in Cornell University from 1883 to 1885. In 1893 he was secretary of the division of marine engineering of the International Engineering Congress and in 1897 delegate representing the navy department at the Congress of Naval Architects and Marine Engineers. Mr. McFarland was an assistant to the engineer in chief of the navy from 1889 to 1894 and during the years 1897-8 was principal assistant. Since 1899 he has been connected with the Electric Company, since 1900 as acting vice president. He was lecturer on engineering subjects for Cornell University from 1900 to 1904.

G. E. MILLER (Univ. of Missouri, '95), after graduation, spent several years in educational and engineering work; came with the Electric Company in 1899, devoting most of his time to special work in the sales department. He is now assistant to the manager of the railway and lighting department.

ANDREW McTIGHE was in the detail department of the Electric Company for a number of years. In 1904 he entered the erecting department as expert on instruments and detail apparatus.

N. J. NEALL (Mass. Inst. of Technology, '00), after graduation, served an apprenticeship with the Pennsylvania Railway. Mr. Neal was for a number of years an engineer with the Electric Company engaged in the development of protective apparatus. While with the company he traveled all over the country visiting power stations and securing a large amount of data on lightning protection. He has recently opened a consulting engineering office in Boston.

F. D. NEWBURY (Cornell, '01) entered the employ of the Electric Company in 1901 as an engineering apprentice. Since 1903 he has been in the engineering department. He was the first editor of THE ELECTRIC JOURNAL and is now a member of its publication committee. He is now serving his second term as president of the Electric Club.

L. A. OSBORNE (Cornell, '01) entered the Newark works of the Electric Company; engaged in erection and testing work, such as the calibration of instruments; came to East Pittsburg after the removal of the Newark works; was connected with the superintendent's office, worked out a new system of production, which is the basis of the present system; was made assistant superintendent in charge of production and was later made assistant to vice president, then manager of works, fourth vice president, third vice president, and second vice president in charge of the engineering and sales departments, which position he now holds.

GEORGE PARSONS (Cornell), after working with a number of electric light and power companies, served a few months on the Electric Company's apprenticeship course and in the process department on economy of manufacture and then entered the manager of works department where he is now an acting assistant superintendent.

J. S. PECK (Cornell, '92) entered the employ of the Electric Company in 1893, was in the students course for a number of months, after which he was transferred to the laboratory. From 1895 to 1904 Mr. Peck was in charge of the transformer engineering office. He is at present consulting electrical engineer of the British Westinghouse Company.

T. S. PERKINS (Worcester Politechnic Institute, '93), after several months on the apprenticeship course of the Electric Company, entered the detail engineering department in 1894. Before taking up electrical work, he was assistant assayer and later assistant superintendent of the Pennsylvania Lead Company. His present position is head of the detail and supply division of the engineering department of the Electric Company.

C. S. POWELL (Ohio State Univ., '93) entered the apprenticeship course of the Electric Company; was connected with the correspondence and sales departments; manager of the Cleveland office; was connected for several years with the British Westinghouse Company. He is now located in New York as general agent of the Electric Company.

H. G. PROUT (Univ. of Mich. and Yale) was in the Civil War from 1863 to 1865. He entered U. of M. in 1867, graduated as a civil engineer; was engaged on a survey of the Great Lakes and later on railroad surveys and on reconnaissance work in the Rocky Mountains for the government. For nearly five years he was in the service of the Khedive of Egypt as major of engineers and attained the rank of colonel in the general staff. After returning to this country he was with the old Switch & Signal Company for a short time, and in 1887 became editor of the Railway Gazette. He was one of the editors of the Encyclopedia Brittanica and has done a large amount of writing for magazines and the daily press. He has held office in a number of engineering societies. For a number of years past he has been vice president and general manager of the Union Switch & Signal Company.

W. E. REED (Mass. Inst. of Technology, '97) took the Electric Company's student or shop course during the years 1891 to 1893. He studied for some time in Paris in the laboratory of Professor Henri Moissan, the chemist and electro-installingist, whose work included the making of the first practical electric furnace. From 1898 to 1900 Mr. Reed was designing engineer of the Societe Anonyme Westinghouse, Havre, France, and from 1900 to 1903 was their chief electrician. His present position is designing engineer with the Electric Company, where he makes a specialty of induction motor design.

C. W. RICKER (Mass. Inst. of Technology, '01) took the General Electric Company's student course and then went into business for himself as a mechanical engineer. Later he became electrical engineer for the Electric Securities Company; with local companies department, General Electric Company, after which he was with the Cleveland Construction Company, and with the New York Central Railway in their traction department. He has been superintendent of power stations of the Interborough Rapid Transit Company, of New York, until quite recently, when he accepted his present position of electrical engineer of the Cleveland Construction Company.

E. P. ROBERTS (Stevens Inst. of Technology, '77) was for some years assistant engineer for the United States Electric Company. He was erecting engineer for the Rocky Mountain Brush-Swan Company, and manager and consulting engineer for a number of other western companies. He then became associate professor of electrical engineering at Cornell University and later manager of the Swan Lamp Mfg. Company. In 1893 he formed the engineering firm of E. P. Roberts & Company, of Cleveland, which later became the Roberts & Abbott Company, of which he is now president.

M. C. RYPINSKI (Rose Polytechnic Inst., '97) was with the General Electric Company from 1897 to 1902 in the instrument engineering department.

From 1902 to 1904 he was superintendent of the Empire Electric Instrument Company. He organized and was president of the Simplex Company, of Newark, N. J. At present he is a meter expert in the engineering department of the Electric Company.

C. F. SCOTT (Ohio State Univ. '85) took graduate work at Johns Hopkins University while instructor in the B. & O. R. R. Technological School for apprentices; began electrical work as a wireman at the Baldwin Locomotive Works; entered the Electric Company 1888 in the testing room; assisted Mr. Tesla in early work on induction motors; was laboratory assistant, assistant electrician, electrician, chief electrician, and is now counsulting engineer; is a member of the publication committee of THE ELECTRIC JOURNAL.

F. H. SHEPARD has been identified with heavy railway work from its beginning. He was active in the original installation at the Baltimore tunnel. He has given particular attention to multiple-control work and is now connected with the Electric Company.

S. L. SINCLAIR for several years was with the Electric Company's district engineer at Philadelphia and later was transferred to Cleveland. He afterwards accepted a position with the D'Olier Engineering Company in Philadelphia, but about a year ago returned to the Electric Company and is now connected with the erecting department in New York.

C. E. SKINNER (Ohio State Univ., '90) entered the Electric Company's controller department and was subforeman and later was in the armature winding department as inspector; an investigation of certain difficulties in insulation was the beginning of many years of specialization in the preparation and use of insulating material and methods of testing; he has become an expert in the use of materials in electrical apparatus, and is now head of the research division of the engineering department.

E. H. SNIFFIN became associated with Westinghouse, Church, Kerr & Company in 1886, first as a salesman and afterwards as sales manager. In 1903, when the Machine Company organized a sales department, Mr. Sniffin was made sales manager. In addition to his position as sales manager he was in 1905 elected third vice president.

K. E. SOMMER (Cornell, '96) began with the Electric Company as a student. He entered the erecting department in 1900 and is now district engineer at the Baltimore office.

W. R. STINEMETZ (Lehigh, '93) was with G. O. Braniff, Mexico, one year. In 1896 he came to the Electric Company as a special student and in 1901 entered the erecting department. He was transferred in 1905 to the French Westinghouse Company to take charge of single-phase railway installations in Italy.

N. W. STORER (Ohio State Univ., '91) entered the Electric Company's student course and was later in charge of electrical work in connection with the drafting department and experimental and commercial testing; for a number of years he had charge of the engineering work in connection with direct-current motors and generators, and is now head of the railway division of the engineering department.

H. G. STOTT (College of Arts and Sciences, Glasgow) was for four and one-half years assistant electrician for the Anglo-American Telegraph Company when he went to the Brush Electrical Engineering Company, of London. On coming to this country he was for nine years electrical engineer of the Buffalo General Electric Company. He is at present superintendent of motive power of the Interborough Rapid Transit Company, of New York City.

C. F. STREET was with the Buckeye Engine Company for three years as an apprentice and in drafting department. For four years he was chief draftsman of the Chicago, Milwaukee & St. Paul Railway and for one year was in the engineering department of the Allis-Chalmers Company. For seven years was editor and manager of the Railway & Engineering Review. He spent a year in making a tour around the world in the interests of the Field Columbian Museum of Chicago. For three years he was manager of the railway department of the Dayton Malleable Iron Company and for three years manager of the railway department of the Wellman - Seaver - Morgan Company. His present position is commercial engineer for the Electric Company.

H. R. STUART took a special course at Mass. Inst. of Technology. He entered the employ of the Electric company in 1897, and after a year or two in the drafting department, entered the detail engineering department. At present he is engineer for the American Telegraphone Company, of Wheeling, W. Va.

J. W. SWEENEY has been with the Electric Company since 1888 and had charge of some of the early important installations. He was in France for five years installing and operating some large power stations, after which he was for two years with the British Westinghouse Company. Since returning to this country he has been in the Electric Company's erecting department.

H. B. TAYLOR (Univ. of Tenn., '98) spent the two years following his graduation in the testing and engineering departments of the Electric Company, after which he was employed in the drafting room of the Union Iron Works, San Francisco, for a short time. On his return to the Electric Company he went into the engineering work on switchboard design. The following year he took charge of the standard house and the standardizing of precision instruments, which position he now holds.

P. H. THOMAS (Mass. Inst. of Technology, '93) entered the student course of the Electric Company and was inspector of returned transformers; his minute and analytical method of inspection was a good basis for his subsequent experimental work on insulating material and his investigations of high-tension phenomena and protective apparatus; for several years he has been connected with the Cooper-Hewitt Electric Company, of which company he is now electrician.

W. H. THOMPSON (Purdue, '98) was employed by the Wagner Electric Mfg. Company from 1899 to 1901. Since 1901 he has been with the Electric Company. At present he is an engineer in the transformer engineering department.

CALVERT TOWNLEY (Yale, '86) entered the Electric Company in 1887; was successively road engineer, assistant to the general agent, salesman, in charge of office and correspondence under the vice president, assistant to the first vice president in New York, manager at Boston, general agent located at New York; for two years has been at New Haven, and is now first vice president of the Consolidated Railway Company and consulting engineer for the New York, New Haven & Hartford Railway Company.

THEODORE VARNEY (Mass. Inst. of Technology, '94) has successively held the following positions: One year with Jenney Electric Motor Company; two years with the Commercial Electric Campany; four years as electrical inspector with the National Board of Fire Underwriters at Chicago; for the last five and one-half years has been with the Electric Company in the detail and railway engineering departments.

F. C. VEHSLAGE is one of the Electric Company's single-phase railway experts. He has been with the company about twelve years.

J. E. WEBSTER (Univ. of Wisconsin, '94) took the apprenticeship course with the Electric Company, after which he entered the engineering department. For some time he was section engineer on railway motors, general engineer in the railway division.

G. B. WERNER (Columbia, '05) entered the apprenticeship course of the Electric Company in 1905.

E. C. WHEELER was in various departments of the Electric Company from 1898 to 1902. After a year in Mexico with G. O. Braniff Company, he entered the erecting department. He has been in charge of a number of large installations in Mexico and Canada and is now in Brazil, S. A.

B. WILEY (Rose Polytechnic Inst., '98) was for some time in the electrical department of the U. S. Steel Corporation at the Homestead works. He afterwards was electrical engineer for the Wellman-Seaver-Morgan Company. At present he is with the Electric Company as commercial engineer in charge of steel mill equipments.

R. L. WILSON (Iowa State Univ., Rose Polytechnic Inst., post-graduate at Johns Hopkins) took apprenticeship course with the General Electric Company. He has been through various departments of the Electric Company. For five years he was construction engineer and for three years superintendent of construction. At present he is superintendent of railway construction.

RUDOLPH WINTZER, author of the article on European Gas Engine Practice.

F. E. WYNNE (Bethany, '97 and '98; Ohio State Univ., '02) spent two years in the apprenticeship course of the Electric Company, after which he entered the railway engineering department. At present he is engaged on project work. He is also an instructor in the Casino Technical Night School.

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